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PAPERS

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RAILWAYS.

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Of all the innovations that distinguished the nineteenth century none has had so far reaching an effect, none so greatly beneficial to the whole human race, as the application of mechanical power to transportation, especially on land. Stupendous as have been the results, revolutionary as has been the character of such application, so gradually were the first steps taken that no date can be assigned to the beginning of railways. The earliest illustration of a railway of which the author is acquainted is one shown in a little book on mining engineering by Johan Haselberg, published in 1530. This is a tramway, in which the car is pushed by the miners themselves. Lorini, in his work entitled "Delle Fortificationi", the first edition of which was printed in Venice in 1596, gives probably the first details of a railway, with the rails and flanged wheels of the cars, the cars themselves being hauled by a cable and windlass.

From these, or perhaps from some earlier suggestion, there slowly came into use small tramways, chiefly in connection with collieries, all of which were operated by animal power.

Whether the inception of the employment of mechanical power to work railways should be attributed to the crude locomotive of Trevithick in 1804; or to the rack and pinion device

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[Note:—In the preparation of this paper the author is indebted to various institutions, corporations and individuals for information and assistance, but principally to the Bureau of Railway Economics of Washington, D. C., of which institution a large portion of the staff co-operated in the preparation of the statistics under the personal direction of Mr. Julius H. Parmelee.—Wm. Barclay Parsons.]

of Blenkinsop in 1811; or to John Stevens of Hoboken, New Jersey, who, reasoning from the success achieved by Fulton and from experiments of his own with steam propelled boats, was the first to foresee the modern railway operated by locomotives at high speed for passengers as well as freight, which he described in 1812 in his memorable letter to the Canal Commissioners of New York, advocating such construction across the State rather than the canal then under contemplation; or to the first locomotive of Stephenson placed on the Killingworth colliery line in 1814, or to the Stockton and Darlington Railway in 1825, the first real railway to be completed; or to the recognition of the achieved success of steam locomotion as demonstrated at the Rainhill experiments in 1829, one cannot say. All have justifiable claims to the honor. Since an average of these dates gives the year 1815, it perhaps can be said that the present year marks the completion of the first century of railways.

During that century railways have grown from a most humble beginning, the equivalent of an improved turnpike on which anyone could on payment of tolls run his own vehicles, denounced as dangerous by their opponents, laughed at as visionary by those disinterested, and timidly defended by their adherents, to become the greatest single industry of all times. The combined capitalization of the railways of the world is approximately $50,000,000,000, or twice the estimated wealth of all kinds of the United Kingdom, France and the United States in 1815, while these same railways afford direct employment for not less than 6,500,000 persons, exclusive of those engaged in mining coal and ores to be used by railways, and in the manufacture of rails, rolling stock, equipment, and other railway supplies in establishments other than those operated directly by railways themselves. What this additional number of persons is who thus indirectly earn a living through railways can not be estimated with any accuracy. The above totals are exclusive of local railways in cities and so called "interurban" railways, electrically operated, which latter in recent years have had so extensive a growth, especially in the United States.

This extraordinary development of railways in the comparatively short space of 100 years from nothing to dimensions whose figures can be stated, but not grasped by the mind, is still

TABLE I

MILES OF MAIN LINE OF RAILWAY, REGARDLESS OF NUMBER OF TRACKS, IN EUROPE

Countries	Opening Year of Railways	1830	1840	1850	1860	1870	1880	1890	1900	1910
United Kingdom	1825	95	838	6,621	10,433	15,537	17,933	20,073	21,855	23,389
France	1832	-	309	1,869	5,862	10,830	14,736	20,834	23,623	25,072
Belgium	1835	-	202	388	464	539	1,692	2,936	2,886	2,932
Germany	1835	-	341	3,756	7,229	12,163	21,052	26,660	32,124	38,092
Austria-Hungary	1838	-	89	981	2,823	5,958	11,436	16,437	19,627	23,499
Russia and Finland	1838	-	16	373	987	6,986	14,824	18,164	32,607	41,818
Italy	1839	-	5	265	1,119	3,825	5,340	7,983	9,864	10,538
Netherlands & Luxemburg	1839	-	11	109	208	882	1,443	1,653	2,015	2,250
Switzerland	1844	-	-	17	681	848	1,592	1,926	2,302	2,840
Denmark	1847	-	-	20	69	471	620	1,053	1,674	2,118
Spain	1848	-	-	17	1,192	3,402	4,552	6,211	8,206	9,316
Sweden	1851	-	-	-	324	1,083	3,653	4,979	7,019	8,588
Portugal	1854	-	-	-	85	444	710	1,200	1,346	1,520
Norway	1854	-	-	-	42	223	656	970	1,277	1,848
*Bulgaria	1860	-	-	-	-	-	-	-	-	1,106
European Turkey	1860	-	-	-	41	181	866	1,097	1,952	967
Greece	1869	-	-	-	-	7	7	477	604	982
Roumania	1870	-	-	-	-	152	862	1,580	1,925	1,979
Servia	1884	-	-	-	-	-	-	336	359	494
Malta, Jersey, Man.	-	-	-	-	-	7	37	68	68	68
Total		95	1,811	14,416	31,559	63,538	102,011	134,637	171,333	199,416

*Bulgaria included under European Turkey prior to 1910.

TABLE II

MILES OF MAIN LINE OF RAILWAY, REGARDLESS OF NUMBER OF TRACKS, IN AMERICA

Countries	Opening Year of Railways	1830	1840	1850	1860	1870	1880	1890	1900	1910
United States	1829	23	2,818	9,021	30,635	53,487	87,832	163,597	193,346	240,439
Greater and Lesser Antilles	1837	-	121	263	391	402	971	1,453	1,908	3,368
Canada	1840	-	16	71	2,087	2,497	6,891	13,256	17,657	24,731
Mexico	1850	-	-	7	20	217	696	6,090	9,055	15,260
Peru	1851	-	-	-	55	255	1,151	1,036	1,036	1,584
Chile	1852	-	-	-	121	455	1,119	1,926	2,850	3,526
Brazil	1854	-	-	-	80	429	1,988	5,903	9,195	13,279
Colombia	1855	-	-	-	48	64	75	236	400	510
Central America	1855	-	-	-	47	75	131	622	708	1,599
Argentina	1857	-	-	-	24	454	1,560	5,848	10,269	17,384
British Guiana	1864	-	-	-	-	22	22	22	55	104
Paraguay	1865	-	-	-	-	5	45	149	157	157
Venezuela	1866	-	-	-	-	24	70	497	634	634
Uruguay	1869	-	-	-	-	61	230	700	1,144	1,546
Bolivia	1873	-	-	-	-	-	35	130	621	756
Ecuador	-	-	-	-	-	-	37	186	186	333
Newfoundland.	-	-	-	-	-	-	-	111	641	666
Dutch Guiana	-	-	-	-	-	-	-	-	-	37
Total		23	2,955	9,362	33,508	58,447	102,853	201,772	249,562	325,913

without a historical record. Perhaps the development has been so rapid that a proper recording of it has been impossible. This impossibility is fully appreciated by the author of this paper, in the undertaking to lay before this Congress not a history of railways but a summary in figures to show how railways have grown in the various countries of the world, with their equipment, what the earnings have been and are, the rates charged for service, the conditions of employment of the working staffs and the varying methods of ownership and governmental control. The author is fully conscious of the shortcomings of the picture herein presented, that many of the figures are approximate, that omissions are frequent and that some of the statistics are not comparable on account of the varying methods of reporting in different countries. The author ventures to hope that this first attempt to set forth a measure of the railways of the world may lead to other efforts whereby statistics as complete and full as possible may be compiled.

An examination of such statistics of railways as are available indicates how very modern is the science of statistics as applied to transportation. There is, unfortunately, still lacking an agreement in the various countries of the world as to what constitutes a proper basis of railway statistics, and no country has been consistent in the method of collecting its own data. Figures relating to recent years can, in many countries, be obtained without difficulty, but figures earlier than twenty years ago are usually incomplete or are to be received with caution.

To show the development of railways, such figures as are obtainable have been gathered at the end of each decade period beginning with the year 1830 and ending with the year 1910. In some cases the figures given are for the calendar year; in other cases, for the fiscal year, which in the United States ends June 30th.

Tables I to V give the miles of line, regardless of miles of tracks, that were laid at the end of each decade for the several countries of Europe, America, Asia, Africa and Australasia respectively, and the date when the first power operated railway was opened in each country. Table VI gives a recapitulation of the mileage according to continental divisions.

In certain European countries, such as France, the rail-

TABLE III

MILES OF MAIN LINE OF RAILWAY, REGARDLESS OF NUMBER OF TRACKS, IN

ASIA

Countries	Opening Year of Railways	1830	1840	1850	1860	1870	188C	1890	1900	1910
British East Indies	1853	-	-	-	15	36	9,306	16,095	24,707	32,099
Asia Minor and Syria	1860	-	-	-	27	146	231	497	1,715	3,130
Ceylon	1865	-	-	-	-	73	136	191	297	577
Dutch Indies	1867	-	-	-	-	93	280	846	1,301	1,552
Japan including Chosen (Korea)	1872	-	-	-	-	-	73	1,136	3,639	5,130
China	1878	-	-	-	-	-	7	124	401	5,421
Cochin-China, Pondicherry, Tonkin, Malacca, etc.	1879	-	-	-	-	-	7	65	238	2,179
Asiatic Russia	1880	-	-	-	-	-	78	890	1,658	4,066
Malay States	1884	-	-	-	-	-	-	62	273	757
Persia	1888	-	-	-	-	-	-	19	34	34
Portuguese Indies	-	-	-	-	-	-	-	34	51	51
Siberia and Manchuriá	1893	-	-	-	-	-	-	-	3,853	6,738
Siam	1893	-	-	-	-	-	-	-	203	638
Total		-	-	-	42	348	10,118	19,959	38,370	62,372

TABLE IV

MILES OF MAIN LINE OF RAILWAY, REGARDLESS OF NUMBER OF TRACKS, IN

AFRICA

Countries	Opening Year of Railways	1830	1840	1850	1860	1870	1880	1890	1900	1910
Egypt	1856	-	-	-	275	656	932	961	1,389	1,453
Algeria and Tunis	1862	-	-	-	-	321	857	1,929	2,641	3,134
Belgian Kongo Colony	-	-	-	-	-	-	-	-	-	516
South African Union:										
Cape Colony	-	-	-	-	-	-	-	-	-	3,772
Natal	-	-	-	-	-	-	-	-	-	1,093
Central South African Rys.	-	-	-	-	-	-	-	-	-	2,589
Rhodesia Railways	-	-	-	-	-	-	-	-	-	2,192
Colonies										
Germany										
German East Africa	-	-	-	-	8	133	1,098	2,942	7,770	446
German Southwest Africa	-	-	-	-	-	-	-	-	-	993
Togoland	-	-	-	-	-	-	-	-	-	185
Kamerun	-	-	-	-	-	-	-	-	-	66
Great Britain	-	-	-	-	-	-	-	-	-	1,807
France	-	-	-	-	-	-	-	-	-	1,360
Italy	-	-	-	-	-	-	-	-	-	71
Portugal	-	-	-	-	-	-	-	-	-	1,002
Total		-	-	-	283	1,110	2,887	5,832	11,800	20,679

TABLE V

MILES OF MAIN LINE OF RAILWAY, REGARDLESS OF NUMBER OF TRACKS, IN AUSTRALASIA

Countries	Opening Year of Railways	1830	1840	1850	1860	1870	1880	1890	1900	1910
Victoria	1854	-	-	-	94	275	1,199	2,687	3,219	3,504
South Australia	1854	-	-	-	64	190	667	1,802	1,882	2,082
New South Wales	1855	-	-	-	70	339	850	2,262	2,810	3,784
New Zealand	1863	-	-	-	-	44	1,288	1,809	2,104	2,717
Queensland	1865	-	-	-	-	206	633	2,134	2,801	4,012
Tasmania	1870	-	-	-	-	43	167	400	479	634
Western Australia	1873	-	-	-	-	-	72	513	1,363	2,421
Hawaii, Maui & Oahu Islands	1888	-	-	-	-	-	-	-	88	88
Total		-	-	-	228	1,097	4,875	11,607	14,746	19,242

TABLE VI

MILES OF MAIN LINE OF RAILWAY, REGARDLESS OF NUMBER OF TRACKS

SUMMARY

Continent	Opening Year of Railways	1830	1840	1850	1860	1870	1880	1890	1900	1910
Europe	1825	95	1,811	14,416	31,559	63,538	102,011	134,637	171,333	199,416
America	1827	23	2,955	9,362	33,508	58,447	102,853	201,772	249,562	325,913
Asia	1853	-	-	-	42	348	10,118	19,959	38,370	62,372
Australasia	1854	-	-	-	228	1,097	4,876	11,607	14,746	19,242
Africa	1860	-	-	-	283	1,110	2,887	5,832	11,800	20,679
Total		118	4,766	23,778	65,620	124,540	222,745	373,807	485,811	627,622

ways are divided into two classes—those of general interest and those known in France as ‘‘intérêt local’’. The statistics contained in this paper refer only to the railways of ‘‘intérêt gén-

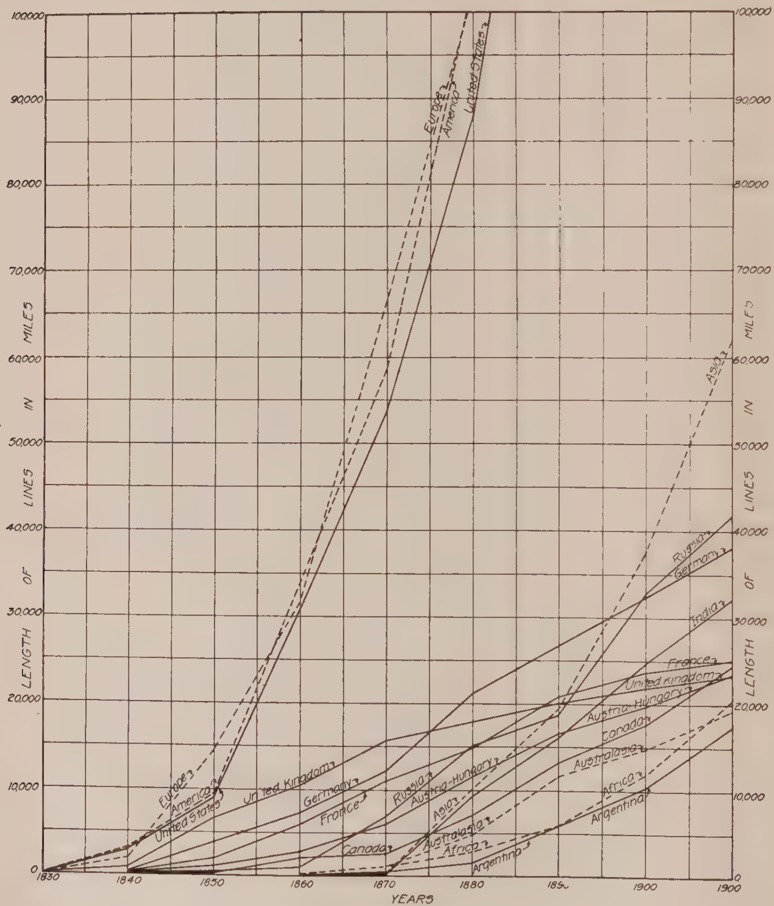

Diagram 1.

éral’’, as they are denominated in France, and the mileage, therefore, of the minor lines, together with other traffic figures, has been omitted. In 1910 such minor lines in France aggregated 5,562 miles, in Belgium 2,356 miles, in Austria-Hungary 4,072 miles, and to a much less extent in the other countries.

Omission of railways of "intérêt local", or industrial railways, accounts for some apparent differences in the figures in this paper and figures sometimes published.

The information shown in Tables I to VI is shown diagrammatically in Diagram 1, in so far as the continental divisions are concerned and nine selected leading countries of Europe, America and Asia.

An examination of these tables discloses some interesting changes in position. The United Kingdom, where the modern railway had its birth, led all European countries in mileage until 1870. By 1880, however, the premier position was taken by Germany. In 1890 France's mileage surpassed that of the United Kingdom, and in 1900 Austria and Russia had done likewise. The growth of the last named country has been the most rapid. In 1850 its mileage was negligible; in 1860 it stood seventh; in 1870, 1880 and 1890, fourth; in 1900 it was practically on an equality with Germany for second place, and in 1910 it was easily first.

If the United Kingdom led European countries for over forty years, it had quickly taken second place to the United States, which already in 1840 possessed more than three times as many miles of line as the United Kingdom, and 1,000 miles more than all Europe. The more rapid spread of railways in the well populated countries of Europe, while still always leaving the United States possessed of more miles of line than any other one country, had reduced the United States and all America to second place in 1850; and it was not until thirty years later that American mileage exceeded European, and not until the decade of 1890 that the miles of line in the United States alone were greater than those of the whole of Europe.

The year 1870 is seen to be a critical year in the development of railways generally throughout the world. In this year the United States increased its rate of growth, the United Kingdom seriously decreased its growth, and Germany showed the effects of the war with France and entered upon a period of rapid growth which extended over the next ten years. The rate of growth in France was somewhat checked, while Russia, Austria and Canada increased their rate. The country, however, which showed the greatest change was India, following the establish-

TABLE VII

Country	Miles of Line Per 100 Sq.Mi.	Miles of Line Per 10,000 Inhabitants
Argentina	1.9	42.2
Austria-Hungary	10.9	5.6
Belgium	47.2	7.3
Canada	0.8	41.1
Denmark	15.8	9.1
France	15.1	8.0
Germany	18.7	5.9
United Kingdom	19.3	5.2
India	1.8	1.1
Italy	9.8	3.2
Japan	2.7	1.1
Netherlands	15.4	3.4
Norway	1.6	8.2
Russia & Finland	1.9	3.0
Spain	5.0	5.1
Sweden	5.1	16.2
Switzerland	18.7	8.4
United States	8.3	26.7
Continent		
Africa	0.2	1.5
America	2.4	21.0
Asia	0.4	0.8
Australasia	0.6	36.0
Europe	5.6	4.8

ment in that year of a governmental system for the development of that country's transportation facilities.

To state simply totals of miles of railways gives no value of comparative density. Both area and population should be considered. When countries are thus compared their relative standing is greatly altered. Selecting the more important of the countries of the world, the miles of line per 100 square miles of territory and per 10,000 inhabitants for the year 1912 are shown in Table VII.

When a comparison is made of miles of line as related to area, Belgium—when the secondary lines are included—is easily the leading country, there being twice and a half as many miles as are found in the United Kingdom, and a still larger ratio than in Germany. If the United States possessed the same proportion of miles of line to area there would be at present nearly 1,500,000 miles, while Russia in Europe would be served by more than 950,000 miles. In Europe, Norway has the smallest amount of line for its area, being only 1.6 miles per 100 square miles. On the basis of population, Argentina and Canada are the most liberal. Sweden takes the lead in Europe with 16.2 miles per 10,000 inhabitants, while the Balkan States are the lowest in the scale.

In order to ascertain the extent of the service rendered by railways it is not necessary to burden this paper with details of railways in countries which constitute but a comparatively negligible portion of the whole. By reference to Tables I to VI, it will be seen that the railway systems of Argentina, Austria-Hungary, Belgium, Brazil, Canada, Denmark, Egypt, France, Germany, India, Italy, Japan, Netherlands, New Zealand, Norway, Portugal, Roumania, European Russia, Spain, Sweden, Switzerland, the United Kingdom and the United States constitute 85 percent of the world's mileage and a very much higher percent of the world's traffic.

Statistics at the end of each decade period of the various countries in this list have been compiled, so far as they are available, covering the length of line, length of additional main tracks, capital, rolling stock, operating revenue and expense, total number of passengers and tons carried, number of passengers and tons carried per unit of distance, and the receipts for such unit,

and the number and compensation of employes. These figures are shown in Tables VIII to XXX inclusive.

In examining these statistics it will be seen how the various countries differ from each other in the manner in which the statistics are kept. It is a source of much regret that the United Kingdom is one of the least progressive, although in some of the British colonies, such as Canada, the opposite course has been followed. In the United Kingdom, with but one or two striking exceptions, no account is kept of the passenger- and ton- miles, so that it is impossible to compare the results of operation of British railways with those of other countries. The number of passengers reported as carried is also deceptive. On account of the system of season tickets in vogue in the United Kingdom the total number of passengers is exclusive of this very large volume of travel. On the other hand, the local rapid transit lines, such as the underground and tubular railways in London, are regarded as main lines and their heavy passenger traffic goes to swell the total number of passengers carried, although the miles of railway of such lines as compared with the grand total is almost negligible. In the United States, France and Germany such lines are not considered as part of the country's railway mileage and the number of passengers carried is not included.

Great as is the number of passengers carried on the various railways of the world, it is interesting to point out that during the year ended June 30, 1914, the number of passengers paying cash fares, exclusive of transfers, on the street railways of the City of New York amounted to 1,813,204,692, a number greater than the total number of passengers carried in any country of the world and substantially twice the number carried by all the steam railroads in the United States.

Units in the above mentioned tables are those used in the various countries. In order to provide a ready means of comparison, Table XXXI gives the relation of the several units of these various countries, with those of the corresponding units used in the United States. This same table can, without difficulty, be used to translate units of one country into those of any other country by combining the representative decimal factors. Thus, if a kilometer is .621 and a verst .663 of a mile, a kilometer is .621 divided by .663 verst or .937 verst, and in like

manner a verst is .663 divided by .621 kilometer, or 1.068 kilometer.

In order that the railways of the various countries can be readily compared, the statistics for the year 1910 have all been converted into American units and the totals have been divided by the miles of line in each country so as to get the figures reduced to those per mile of line. In this way the average density of traffic can be obtained. These results are shown in Table XXXII, and to facilitate an inspection of this table the figures are in each case illustrated diagrammatically.

In some countries where a silver standard was in use in 1910 an average rate of exchange for the year was determined from the most reliable figures at hand.

It is regretted that for certain countries recent statistics were not procurable and for other countries covering only a portion of the system. On account of the disturbed political condition of Mexico no Mexican figures worthy of presentation have been procured. For Brazil the year 1908 is the last year available; in Egypt the figures cover the state railways only and omit the private lines. In Italy the figures for the private lines were not obtainable for the year 1910, and approximate figures derived from the statistics of 1907 have been used. In Spain the figures for 1909 are used in lieu of 1910, the latter not being available.

An examination of this table shows the great extent of the railways in the United States whenever totals are stated, except in passengers carried and the total number of passenger train cars. In the first regard it takes third place to Germany and the United Kingdom, and in the latter, fourth place to the United Kingdom, Germany and France. This last statement, however, indicates the danger of drawing conclusions from statistics without a thorough understanding of the statistics themselves. In the United States the seating capacity of the ordinary passenger car is very greatly in excess of the seating capacity of corresponding cars in the other countries named, so that in spite of fewer cars, the total capacity of passenger train cars in the United States is greatly in excess of that of any other country. This same relative comparative capacity is still more marked in the case of freight cars and the mere numbers of freight cars used in different countries per mile of line gives no

idea of the total capacity of such cars, those used in the United States being in some instances many times larger than those used in other countries.

When, however, the figures are reduced to a basis of per mile of line the real value of density is determined and the universal preponderance of the United States then ceases to exist. The most striking manner in which the railways of the United States exceed the railways of the other countries is in the volume of their freight traffic. Even when the tons carried one mile are reduced to a basis of per mile of line the United States shows the greatest total, the second country being Germany, figures for Great Britain being unobtainable. When, however, the tons carried one mile are compared, without the per mile reduction, it will be seen that the ton-miles in the United States are 7 times greater than those of Germany, 57 times greater than the ton-miles of Argentina, 17 times greater than Austria-Hungary, 520 times greater than Brazil, 16 times greater than Canada, 895 times greater than Denmark, 17 times greater than France, 19 times greater than India, 117 times greater than Japan, 1,270 times greater than Norway, 12 times greater than Russia in Europe, 121 times greater than Spain, 140 times greater than Sweden, and 299 times greater than Switzerland.

If the freight tonnage of the United States greatly exceeds, both in volume and density, that of other countries, the same is not true of the passenger travel. Not only is the total number of passengers less, but the number carried per mile of line is very much less, being lower than Austria-Hungary, Belgium, Canada, Denmark, Egypt, France, Germany, India, Italy, Japan, Netherlands, New Zealand, Norway, Portugal, Roumania, Russia in Europe, Spain, Sweden, Switzerland and the United Kingdom. On account of the great size of the United States, as might be expected, the total number of passenger miles exceeds that of any of the other countries that record such figures, but when the total number of passenger miles is divided by the total number of miles of line, the United States takes position with Norway, Spain and Sweden, while Belgium becomes the leading country in the world, with a density more than twice as great as that of France and nearly twice that of Germany, while Japan is second to Belgium.

The return for service rendered is shown in the receipts per passenger- and per ton-mile, and again it becomes unfortunate that the United Kingdom has never compiled statistics on this basis. The country with the lowest receipts per passenger mile is India, .414c., and the most expensive is the United States, 1.938c., with Canada second at 1.866c. These figures by themselves, however, give a very unfair comparison. In the United States and Canada there is practically but a single class, except that a very small proportion of the traveling public pay an additional fare for Pullman service. In the other countries of the world there are class graduations, in some instances as many as four, and a great number of passengers are carried in these countries at extremely low rates of fare but with a correspondingly inadequate service. In some countries passengers are loaded in open freight cars and in many countries the lowest class are carried in cars roofed over but without seats. The third class, where such service is furnished, is usually about one-third of the first class fare, and the majority of the people take the lower class, which brings the average down. If charges could be obtained in other countries for service comparable to that offered in the United States and Canada, with comfortable seats, steam heat in winter, toilet and other accommodations and fast express service, those two countries would be found at the bottom and not at the top of the list, so far as charge for service rendered is concerned. When, however, the receipts from freight per ton mile are considered, India, Canada, Japan and the United States are close competitors for the lowest charge, their position being in the above order but the difference being negligible. Upon this cost of service, Column 31, of Table XXXII, Sheet No. 6, which indicates the average yearly compensation of employees has considerable bearing. There it will be seen that for the countries where such figures are obtainable the average compensation of the United States is greatly in excess of that of any other country, being nearly twice that paid in Germany and more than twice that paid in Austria-Hungary, and six and a half times that paid in Japan.

The preceding tables show the general development of railways in respect to mileage, equipment and traffic. It is an extraordinary thing that at the end of 100 years of growth the

general mechanical principles of the motive power used on railways are the same as those developed by Stephenson in his original engines. The detail of compounding has been introduced, but otherwise the general features, except as to size, of the locomotives used now and then are the same; that is, a high pressure steam engine, with tubular boiler and cylinders in pairs, exhausting into the smoke stack. In size, however, the change has been most radical. From Stephenson's ''Rocket'', with its single pair of driving wheels and total weight of 4.25 tons, we have reached an engine with 24 driving wheels, three pairs of cylinders, and the weight of the engine being 426 tons, including the tender, whose weight is used for traction, power being applied to its wheels.

In this great increase in size of rolling stock the United States has been easily the leading country. With the great distances to be traversed, with the low rates of freight, and with the comparatively low density of traffic, as compared with European countries, there has always been great pressure for extreme economy, which can be reached in part by using the minimum number of trains with the maximum capacity not only of each train, but of each unit in the train.

In regard to locomotives, the first one used in the United States was the ''Stourbridge Lion'', imported from England in 1829 and actually used for a short time on the line of the Delaware & Hudson Canal Company, but this stupendous machine, which stood on four driving wheels and weighed the great amount of 8 tons, was found too heavy for actual service and was speedily abandoned, and for the next two years the locomotives used in the United States were machines of less weight and less power. The failure of the ''Stourbridge Lion'', on account of its excessive size, did not, however, long deter either the railway operator from calling for increased power of his engines nor the ingenuity of the locomotive builder to produce engines of greater and greater weight. In 1832 the Baldwin Locomotive Works turned out their first machine, of a weight of 10,000 pounds, and from that time until the present the increase in the size of the locomotives has not ceased.

Table XXXIII gives a list of the locomotives as each in turn established a new high record. This table shows the year in

which the engines were turned out, the railway on which used, the shops in which built, the sizes of the cylinders and the driving wheels, the service employed, and the total weight of the engine. The type of each engine is described according to the Whyte system, in which the first figure represents the number of wheels in the guiding truck, the second figure the number of driving wheels, and the last figure the number of wheels in the trailing truck. In certain cases it will be noticed that there is more than one set of figures denoting drivers. Such combination indicates an articulated engine and the number of drivers in each section.

In this table it will be seen that the growth of the engine, as indicated by weight, was substantially uniformly constant down to the year 1889, up to which time the heaviest freight engine was one weighing 154,000 pounds, with cylinders of 21 in. diameter by 36-in. stroke, and the heaviest passenger engine one weighing 127,000 pounds, with compound cylinders 20-39 in. by 24-in. stroke. Up to this time heavier locomotives were in use in Europe than in the United States. In fact, as early as 1863 there was placed upon the Northern Railway of France an engine weighing 135,000 pounds and of the type 0.6.6.0, when the heaviest American locomotive was a pusher engine weighing 100,000 pounds. In 1891 the Erie, with its 195,000 pound compound, challenged Europe for the supremacy in heavy engines, which position the United States has not since lost, and from that period, as will be seen by the table, the weights of its engines have grown at a most astonishing rate, both as to passenger and freight, reaching the present climax in 1914, when the Erie once more took the lead with an engine of a total weight of 853,050 pounds. It is interesting to note that the Pennsylvania passenger locomotive of 1911, with its weight of 317,000 pounds, was almost as large as the record freight locomotive of only seven years previous on the Baltimore & Ohio.

The development of the freight car has been parallel with the development of the locomotive, beginning with the cars which were loaded with two tons, which were to be hauled by the "Stourbridge Lion". In the details of their growth, however, early statistics are not as available as in the case of locomotives.

Prior to the year 1902 no complete classifications of American equipment were kept. Beginning with that year the Interstate Commerce Commission has required the railroads not only to report the total number of cars in service, but to report the number of cars of various capacities.

Up to about the year 1880, the size of the American freight car, while generally larger than the European car, did not differ in any striking degree from its European counterpart. Although the double truck, 8-wheel freight car was in general use, a large part of the coal traffic of the country was still being carried in two-axle cars, known as "Jimmies", corresponding to the British "waggon", with a capacity of 5, and of the larger cars 10, tons; and the standard two-truck freight car was a car with a capacity not exceeding 30,000 pounds.

With the gradual replacement of iron by steel rails, and the general improvement of roadbed, the railway managers of the United States appreciated the fact that the largest car was the most economical, and in about the year 1882 a freight car of 40,000 pounds capacity was adopted as the standard car. The success of this car quickly led to cars of a greater capacity and during the decade 1890 to 1900 the demands for such cars were more and more pronounced. In about 1897 the Pittsburgh, Bessemer & Lake Erie Railroad placed an order for a car of 100,000 pounds capacity, which had been frequently talked of but had never been put into successful operation. With the practical introduction of this car it was felt that for the moment at least the pendulum had swung too far, and for a great deal of traffic, even for coal traffic, the car was too large, and a car of the capacity of 80,000 pounds came into use, quickly passing the 100,000 pound car in numbers.

Table XXXIV shows the number of cars of various capacities in use in the United States from the year 1902 to 1914, both inclusive, by which it will be seen how the cars of the lower capacity have been steadily dropping out and the increase has taken place wholly in the cars of the larger capacity, so that the average capacity of the freight car in existence has risen from 28 tons in 1902, to 39 tons in 1914, an increase of nearly 1 ton per year or 40 percent in 12 years.

In order to simplify an examination of these figures, Diagram 2 has been prepared, showing the numbers of cars of capacity of 40,000, 50,000, 60,000, 80,000, and 100,000 pounds in use in the various years from 1902 to 1914. This diagram shows that the 40,000 pound cars, which 30 years ago were supposed to be the last word in car construction, have been steadily decreasing so that in 1914 there were less than 49,000 in existence. The 50,000 pound car, which was never a very great success because car designers appreciated almost immediately after its introduction that the 60,000 pound car was equally feasible and much better, has, like the 40,000 pound car, been steadily decreasing, but, curiously enough, at nothing like so high a ratio, so that while there never was as great a number of them constructed as of the smaller car there were more left in existence from 1908 to 1914.

The curve shown by the number of 60,000 pound cars is particularly interesting. This car is shown to be steadily increasing in number from the time it was first introduced to the year 1908, by which time the great advantages of cars of still greater capacity were more fully appreciated, and from that year the 60,000 pound car has been decreasing in number slowly until 1911, and at an increasing ratio from that period to date. The curve shown by this car would correspond to the curves for the 40,000 and 50,000 pound cars, if those curves could be extended back to the time of their first introduction, increasing to a certain point of maximum popularity and then decreasing as each in turn was surpassed by a car of greater capacity.

The 80,000 and 100,000 pound cars have steadily increased from the time of their introduction, with the exceptions of the years 1910 and 1911 when the 100,000-pound car and the 80,000-pound car, respectively, temporarily decreased. From that year on both cars have increased, except that the diagram shows the 100,000 pound car is increasing at a higher ratio than the 80,000 pound car, and bids fair soon to surpass it, just as the 80,000 pound car, in 1914, passed the 60,000 pound car in total numbers.

That the end has not been reached, certainly not for the average car and apparently not for the maximum size of the ordinary commercial car as differing from a special car for heavy

ordnance or similar concentrated load, it is interesting to note that the Norfolk & Western Railway Company has placed in regular service cars of a capacity of 180,000 pounds.

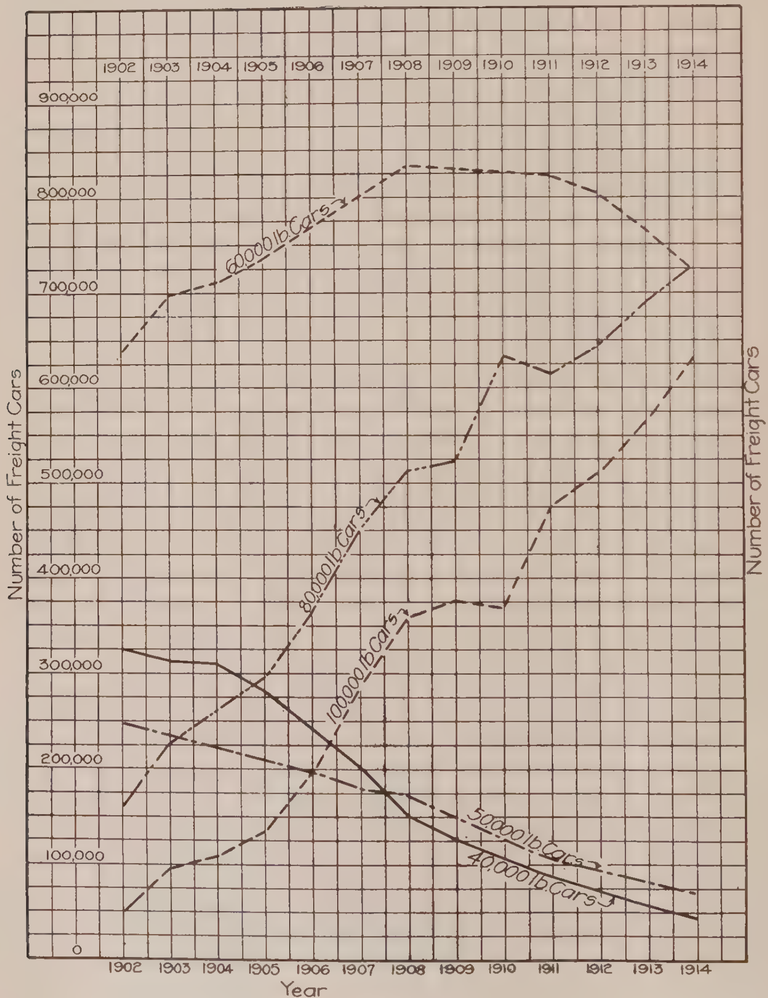

Diagram 2.

Although there is a general tendency throughout the world towards uniformity in railway details, and especially in the promotion of free intercommunication, there is in one important

detail, even in the year 1915, still failing of universal agreement. No one gauge or width of track has been adopted to the exclusion of all others, although the majority of railways use the accidental and inconvenient dimension of 4 feet 8½ inches (1.435 meter). The earliest tramways in England had a gauge of 5 feet (1.524 meter), but the flanges of the wheels were on the outside. When it was realized that it would be more advantageous to have the flanges on the inside, the gauge became 4 feet 8 inches, the flat rails being 2 inches wide. To this figure Stephenson added ½ inch to give greater freedom, thus fastening on the world the unfortunate dimension of 4 feet 8½ inches, a figure without an exact decimal equivalent and that can not in calculation be readily divided or multiplied.

While this gauge has predominated in Great Britain from the beginning, it was not without opposition. Railways in Ireland adopted and have always maintained a gauge of 5 feet 3 inches, while Brunel, with his liking for great things, as shown in the steamer "Great Eastern", constructed the Great Western Railway with a gauge of 7 feet, the widest gauge ever laid, and which remained in service until 1892, when it yielded to the pressure of the demand for intercommunication with other lines and was converted to the then so-called "narrow" gauge, or what is now recognized as the standard. This contest between the adherents of the different track widths forms the chapter of the "Battle of the Gauges" in the development of British railways.

If England can boast of the broadest gauge, it can also boast of the narrowest, that of 1 foot 11½ inches, on the Festiniog Railway in Wales, the smallest gauge ever used in a practically operated railway. This line was authorized by an Act of Parliament in 1832, but was operated by horses until 1863, when steam locomotives were introduced. It is still in service.

On the continent of Europe the English standards and details were copied in the first lines to be constructed, so that the dimension of 4 feet 8½ inches, whose approximate metric equivalent is 1.435 meter, which in computation is quite as inconvenient as the English figures became the standard; but as in England, this gauge has not become universal. Russia, whose railway system was begun without any connection, or perhaps any thought

of connection, with those of other countries, adopted a gauge of 5 feet (1.524 meter), which it has always maintained for military reasons. To this same gauge have the Russian railways in Asia been built, thus breaking continuity with the connecting Chinese lines, which are of 4 feet 8½ inch gauge. Spain also adopted an odd gauge, in this case 5 feet 6 inches (1.676 meter) and maintains it, as the Russians do theirs, with the idea of defense against easy invasion. Portugal has naturally followed its only neighbor. All other countries in Europe have adopted the standard gauge for their main lines, except as in all of them secondary or local lines have been constructed on narrower gauges. With these exceptions, the gauge of 4 feet 8½ inches is the standard gauge of the main lines of continental Europe.

In Asia the Indian railways, the largest Asiatic system, are divided chiefly between a "broad" gauge of 5 feet 6 inches and a narrow gauge of 1 meter. The Chinese lines, except in Yunnan, where they connect with the French railways in Tongking of meter gauge, have been built to the 4 feet 8½ inch gauge. The Siberian lines use the Russian gauge of 5 feet.

In Africa the gauges are mostly 3 feet, meter, and 3 feet 6 inches. In South America there is great diversity, lines being built to gauges of 1 meter, 4 feet 8½ inches, and 5 feet 6 inches. In Mexico, Central America and the West Indies the principal gauges are 3 feet, meter, and 4 feet 8½ inches, with the larger gauge predominating except in Panama, where the gauge is 5 feet.

Table XXXV has been prepared in which nine countries have been selected in Europe, one in South America, two in North America, three in Asia, and two in Australasia, as specimen countries, showing the different gauges and the amount of each in use.

In the United States the greatest number of different gauges of any country have been used, although of late there has been rapid concentration to the standard gauge of 4 feet 8½ inches. The first railways, such as the Baltimore and Ohio and the Delaware and Hudson, copied the Stephenson standard, but in a large country where local and not national interests predominated, and where in the early days the importance of through running was not appreciated, other gauges came into use. In the Southern States a gauge of 5 feet was used quite generally, and in

New York and Pennsylvania, the Erie Railroad, the first long line of importance to be completed, adopted a gauge of 6 feet,

TABLE XXXVI

UNITED STATES RAILWAYS

GAUGES

Gauge	1840 Miles Of Line	1880 Miles Of Track	1889 Miles Of Line	1914 Miles Of Line
6'	-	259	-	-
6' and 4' 9"	-	35	-	-
6' and 4' 8-1/2"	-	2,808	-	-
5' 6"	36	128	-	-
5' 1/2"	-	20	-	-
5'	428	12,282	22	-
4' 10-1/2"	-	21	10	-
4' 10"	343	53	-	-
4' 9-1/2"	-	-	50	-
4' 9-3/8"	-	175	-	-
4' 9-3/8" and 3'	-	14	-	-
4' 9-1/4"	-	260	-	-
4' 9-1/4" and 4' 9"	-	110	-	-
4' 9"	9	12,334	28,939	52
4' 8-3/4"	-	1,925	3,067	-
4' 8-5/8"	-	-	121	-
4' 8-1/2"	2,630	71,403	114,148	243,804
4' 8-1/2" and 3'	-	631	-	10
4' 8-1/4"	-	-	69	-
4' 8"	-	6	935	-
4' 7-1/2"	-	-	1	3
4' 6"	14	-	-	-
4' 3"	-	9	56	-
4' 1"	-	5	8	-
4'	-	-	33	-
3' 11-1/2"	-	-	7	-
3' 11"	-	-		15
3' 10"	-	-	10	-
3' 9-1/2"	-	-	-	21
3' 9"	-	-	12	-
3' 6-1/2"	-	-	8	-
3' 6"	9	307	325	49
3' 4"	27	8	40	-
3' 2"	-	25	4	-
3' 1"	-	-	16	-
3' 1/2"	-	44	-	-
3' 1/4"	-	-	92	-
3'	-	5,191	9,485	3,266
2' 10"	-	-	2	-
2' 9"	-	1	16	-
2' 6"	-	-	5	-
2'	-	18	59	178

with the avowed purpose of keeping other railways from invading its territory. Many of the Erie's connecting lines were built to the same gauge and it was not until about 1890 that the last

portion of it was taken up. During the period from 1870 to 1880, especially in the mountain districts of the West, then being opened to settlement, there was a craze for a narrow gauge, and many were the enthusiasts who claimed that a gauge of 3 feet would soon drive all other gauges out of existence. The number and extent of the various gauges in use at various times in the United States are shown in Table XXXVI. The great diversity of gauges, which continued to increase even until 1889, and the subsequent rapid decrease is strikingly shown. In 1914 the lines whose gauges are other than the standard are lines of minor importance or ones on which there is no through running. It is to be noted in using this table that the figures for 1880 are for miles of track, whereas in the other years they are for miles of line.

Of the 628,000 miles of railway as shown in Table VI as in use in the world in 1910, approximately 440,200 miles are of the standard gauge (4 feet $8\frac{1}{2}$ inches), 88,000 miles are of wider gauge, and 99,800 miles are of narrower gauge, the percentage being as follows:

Standard gauge	70%
Wide gauge	14%
Narrow gauge	16%

It is an unfortunate sequence of the mechanical development of the last century that mechanical operations can not be carried on without a tremendous toll in persons both killed and injured, and the operations of our railways are no exception to this rule. Nineteen countries compile statistics of persons killed and injured, and dividing them into passengers, employees, and persons other than passengers and employees, putting under the last class trespassers and other miscellaneous cases of persons who met with death or injury not as the direct result of transportation, so far as these figures are obtainable they are shown in summary in Table XXXVII, and in detail for 16 countries in Table XXXVIII, for the four last decade periods.

When the numbers killed and injured for the several countries separately are examined the United States stands out with totals that, without explanation, are appalling, and as the figures for the years subsequent to 1910 are readily available the details

down to and including 1914 have been appended, by which it will be seen that in spite of all precautions and improvements the figures are steadily increasing.

So far as the United States is concerned it will be noted that the increase in injured is increasing in a much higher ratio than

TABLE XXXVII

SUMMARY OF PERSONS KILLED AND INJURED

	Passengers		Employees		Others		Totals	
Year	Killed	Injured	Killed	Injured	Killed	Injured	Killed	Injured
1880	446	3,198	2,753	13,856	2,957	2,669	6,156	19,723
1890	660	5,580	4,431	38,923	8,572	6,431	13,663	50,934
1900	976	10,826	5,489	66,058	9,649	15,003	16,114	91,887
1910	1,336	22,302	6,639	138,387	12,720	25,238	20,695	185,927

Countries Reporting Accidents and Included in the above Table.

1880	1890	1900	1910
Austria-Hungary	Austria-Hungary	Austria-Hungary	Austria-Hungary
Belgium	Belgium	Belgium	Belgium
Canada	Canada	Canada	Canada
Denmark	Denmark	Denmark	Denmark
-	-	Egypt	Egypt
France	France	France	France
Germany	Germany	Germany	Germany
India	India	India	India
Italy	Italy	Italy	-
-	-	Japan	Japan
Netherlands	Netherlands	Netherlands	Netherlands
-	-	-	New Zealand
-	-	Roumania	Roumania
Russia	Russia	Russia	Russia
Spain	Spain	Spain	Spain
Sweden	Sweden	Sweden	Sweden
Switzerland	Switzerland	Switzerland	Switzerland
United Kingdom	United Kingdom	United Kingdom	United Kingdom
United States	United States	United States	United States

the increase in killed. In 1880 the ratio of injured to killed was approximately 2 to 1. In 1914 the ratio was 19 to 1, with an increasing ratio for each intervening decade period. This does not mean that there has been so great an increase in persons injured, but rather an increase in the number of injuries reported. In the

earlier years only serious injuries were reported. In later years, on account of an appreciation of the advantage of accuracy in statistics, but more especially undoubtedly on account of greater stringency of liability law and increased possibility for claims for indemnities, injuries are now reported as such that in prior years would have been neglected, both by the companies and by the persons suffering them.

To compare relative safety in different countries, reference must be made to something more than the mere totals. Usually, in the case of passengers the basis of comparison has been the total number of passengers carried, but this again is not fair to those countries where the passenger journey is long, and it would seem as if the proper basis on which to compare the safety to passengers carried is on the number of passenger miles traveled. A comparison between the various countries has, therefore, been worked out (1) on the ratio to the number of passengers carried, and (2) on the ratio to the number of passenger miles. Inasmuch as Italy, The Netherlands and the United Kingdom do not report passenger miles, no comparison with these countries is possible under the last heading.

On the basis of passengers carried, the countries, in 1910, stood in the order of safety as shown in Table XXXIX.

When the countries are reduced to the basis of passenger miles they stand in the order shown in Table XL.

Regarding passengers injured, the respective comparison to passengers carried and to passenger miles is shown in Table XLI and Table XLII.

When comparing employees, the basis has been assumed of per 1,000 employed, figures for which are obtainable in all countries except Italy, The Netherlands, Spain, Sweden and in the United Kingdom. See Tables XLIII and XLIV.

In respect to others than passengers or employees, the basis of length of line has been taken, although a proper basis would be the relative density per mile of line, if such figures could be obtained.

On the basis of miles of line, without regard to density, the countries stand in the order shown in Table XLV and Table XLVI. Of persons other than employees the greater number consists of trespassers.

TABLE XXXIX.

Relative Standing of Various Countries in 1910 in Respect to Passengers Killed per 10 Million Passengers Carried.

	Country	Passengers killed
1.	Belgium	0.56
2.	Germany	0.64
3.	Switzerland	0.64
4.	Netherlands	0.65
5.	Denmark	0.91
6.	United Kingdom	0.93
7.	Austria-Hungary	1.34
8.	Japan	1.37
9.	Sweden	1.37
10.	Spain	2.14
11.	France	2.16
12.	United States	3.33
13.	Italy	3.80
14.	India	5.03
15.	Russia	10.90
16.	Canada	16.70

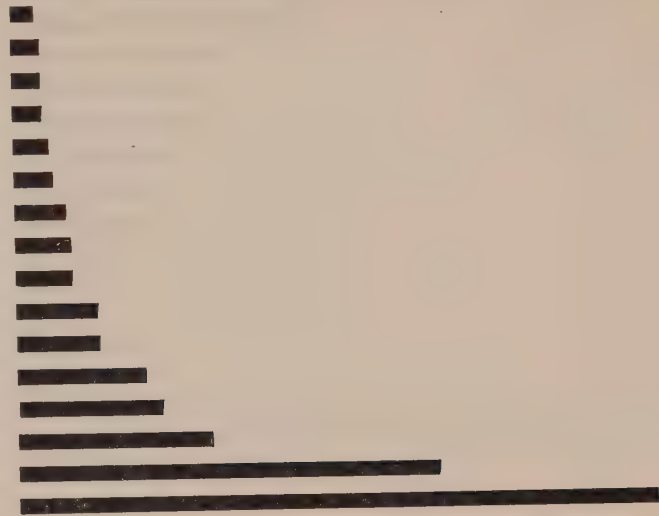

TABLE XL.

Relative Standing of Various Countries in 1910 in Respect to Passengers Killed per 100 Million Passenger Miles.

	Country	Passengers killed
1.	Belgium	0.41
2.	Denmark	0.41
3.	Germany	0.45
4.	Switzerland	0.48
5.	Japan	0.70
6.	Austria-Hungary	0.71
7.	Sweden	0.82
8.	Spain	0.94
9.	United States	1.00
10.	France	1.05
11.	India	1.39
12.	Russia	1.75
13.	Canada	2.43

TABLE XLI.

Relative Standing of Various Countries in 1910 in Respect to Passengers Injured per 10 Million Passengers Carried.

	Country	Passengers injured
1.	Denmark	0.91
2.	Sweden	2.40
3.	Germany	4.30
4.	Switzerland	8.18
5.	Netherlands	9.52
6.	Spain	9.53
7.	France	11.80
8.	Austria-Hungary	13.28
9.	India	17.74
10.	Belgium	18.60
11.	Japan	22.50
12.	United Kingdom	31.15
13.	Russia	55.80
14.	Italy	70.60
15.	Canada	75.20
16.	United States	128.20

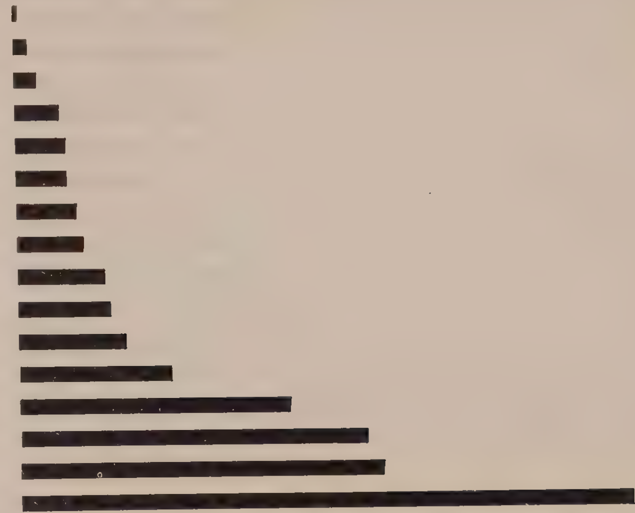

TABLE XLII.

Relative Standing of Various Countries in 1910 in Respect to Passengers Injured per 100 Million Passenger Miles.

	Country	Passengers injured
1.	Denmark	0.41
2.	Sweden	1.43
3.	Germany	3.06
4.	Spain	4.19
5.	India	4.90
6.	France	5.72
7.	Switzerland	6.25
8.	Austria-Hungary	7.06
9.	Russia	8.94
10.	Canada	10.94
11.	Japan	11.50
12.	Belgium	13.45
13.	United States	38.50

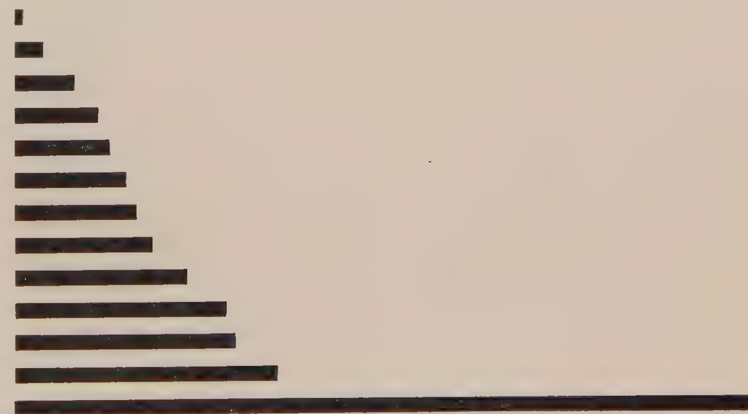

TABLE XLIII.

Relative Standing of Various Countries in 1910 in Respect to Employees Killed per 1,000 Employed.

Country	Killed
1. Italy	0.38
2. Austria-Hungary	0.62
3. Denmark	0.71
4. India	0.73
5. Germany	0.78
6. Russia	0.78
7. Switzerland	0.78
8. France	0.94
9. Belgium	1.04
10. Japan	1.48
11. Canada	1.73
12. United States	2.03

TABLE XLIV.

Relative Standing of Various Countries in 1910 in Respect to Employees Injured per 1,000 Employed.

	Country	Injured
1.	India	1.20
2.	Denmark	1.34
3.	France	1.86
4.	Germany	2.15
5.	Russia	4.37
6.	Austria-Hungary	5.06
7.	Belgium	7.24
8.	Canada	7.48
9.	Italy	9.57
10.	Japan	12.23
11.	Switzerland	32.54
12.	United States	57.30

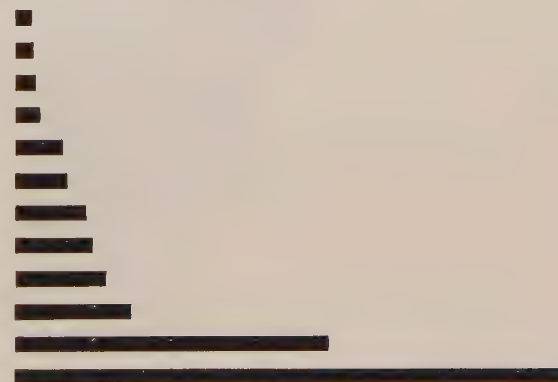

TABLE VIII

ARGENTINE REPUBLIC

Item	Units	1857	1865	1870	1880	1890	1900	1910
Length of Line	Kilometers	10	248	731	2,512	9,415	16,533	27,989
Capital	Pesos	285,108	5,379,898	18,835,703	62,964,486	321,102,691	531,398,720	900,430,051
Locomotives	Number	-	-	-	-	-	-	2,814
Passenger Train Cars	Number	-	-	-	-	-	-	4,346
Freight and Other Cars	Number	-	-	-	-	-	-	61,549
Total Operating Revenue	Pesos	19,185	563,134	2,502,569	6,560,417	26,049,042	41,401,348	110,941,406
Total Operating Expense	Pesos	12,448	438,961	1,356,252	3,072,185	17,585,406	23,732,754	65,929,627
Net Operating Revenue	Pesos	6,737	124,173	1,146,317	3,488,232	8,463,636	17,668,594	45,011,779
Passengers Carried	Number	-	747,684	1,948,585	2,751,570	10,069,606	18,296,422	59,014,600
Passrs.Carried 1 kilometer	Number	-	-	-	-	-	-	2,366,000,000
Tons Carried (Metric)	Number	-	71,571	274,501	772,717	5,420,782	12,659,831	33,606,626
Tons Carried 1 kilometer	Metric Ton Km.	-	-	-	-	-	-	6,570,000,000
Avg.Number of Employees	Number	-	-	-	-	-	-	101,255
Compensation of Employees	Pesos	-	-	-	-	-	-	47,910,000

TABLE IX

AUSTRIA-HUNGARY

		1880	1890	1900			1910		
em	Unit	All Railways	All Railways	State or Operated By State	Private Railways	Total	State or Operated By State	Private Railways	Total
Line	Kilometer	18,415.7	26,469.4	23,376.6	8,229.6	31,606.2	32,173.4	5,667.3	37,840.7
Second Track	Kilometer	1,742.2	2,879.4	1,802.6	2,721.7	5,426.3	5,001.6	1,512.9	6,514.5
	Kronen	6,071,148,478	7,651,357,122	5,684,508,142	3,867,329,070	9,551,837,212	9,979,266,248	2,585,535,643	12,564,801,891
s	Number	3,497	5,272	-	-	8,280	-	-	11,209
Train Cars	Number	9,565	13,897	-	-	20,516	-	-	27,424
d Other Cars	Number	79,642	118,531	-	-	177,389	-	-	233,523
ating Revenue	Kronen	525,548,756	687,764,690	490,880,522	412,667,677	903,348,199	1,174,682,352	280,881,682	1,455,564,034
ating Expense	Kronen	493,666,480	548,981,820	-	-	-	-	-	-
ing Revenue	Kronen	31,882,268	138,782,870	-	-	-	-	-	-
	Kronen	21,810,396	33,184,664	-	-	-	-	-	-
Carried	Number	40,452,395	97,811,991	129,941,799	92,568,509	222,510,308	292,540,152	102,080,379	394,620,531
ried 1 Kilometer	Number	1,964,246,185	3,703,814,869	4,519,630,023	2,994,499,038	7,514,129,061	9,627,439,210	2,298,874,672	11,926,313,882
ts per Passr.Km.	Heller	4.52	3.50	-	-	2.84	-	-	3.09
ed	Metric Tons	49,801,001	92,782,063	68,095,175	85,941,310	154,036,485	139,039,740	57,950,383	196,990,123
ed 1 Kilometer	Metric Tons	4,976,101,999	9,886,326,762	8,585,283,909	6,905,674,246	15,490,958,155	18,047,379,334	3,806,938,721	21,854,318,115
ts per Ton Km.	Heller per Met.Ton	6.32	4.82	-	-	4.23	-	-	4.59
of Employees	Number	127,990	177,142	-	-	295,446	-	-	408,564
on of Employees	Kronen	124,756,330	180,784,668	-	-	324,092,366	-	-	586,941,206

ears 1880 and 1890 items in gulden and kreuzer have
ted into kronen and heller, one gulden being two
one kreuzer being two heller.

TABLE X

BELGIUM

		1835	1840	1850	1860	1870	1880	1890			1900			1910		
Item	Unit	State Railways	State Railways	State Railways	State Railways	State Railways	State Railways	State Railways	Private Railways	Total	State Railways	Private Railways	Total	State Railways	Private Railways	Total
Length of Line	Kilometer	13.5*	324.7*	624.6*	747.2*	868.7*	2,724.0*	3,250.0	1,477.9	4,727.9	4,060.1	587.3	4,647.4	4,330.3	391.4	4,721.7
Length of Second Track	Kilometer	-	-	-	-	-	-	1,334.4	232.2	1,566.6	1,592.2	138.2	1,730.4	2,140.1	162.6	2,302.7
Capital	Francs	4,914,458	77,908,806	167,407,264	206,369,880	279,402,065	1,044,586,844	1,303,086,423	404,300,000	1,707,386,423	1,941,704,561	160,600,000	2,102,304,561	2,731,076,537	107,000,000	2,838,076,537
Locomotives	Number	-	122	170	252	371	1,281	1,977	545	2,522	2,744	293	3,037	4,213	245	4,458
Passenger Train Cars	Number	-	591	1,075	2,219	1,880	3,936	4,726	1,289	6,015	7,031	644	7,675	10,393	491	10,884
Freight and Other Cars	Number	-	746	3,668	6,942	11,497	34,596	43,525	13,304	56,827	64,222	6,481	70,703	84,681	7,764	92,445
Total Operating Revenue	Francs	269,363	5,355,946	15,099,031	29,644,505	45,366,359	113,909,951	141,251,819	40,966,925	182,218,744	209,162,096	28,130,076	237,292,172	309,496,884	31,918,159	341,415,043
Total Operating Expense	Francs	168,847	3,077,994	9,198,980	14,300,788	25,558,033	68,850,660	84,510,102	21,054,885	105,564,987	141,954,099	11,828,518	153,782,617	203,072,380	13,182,789	216,255,169
Net Operating Revenue	Francs	100,516	2,277,952	5,900,051	15,343,717	19,808,326	45,059,291	56,741,717	19,912,040	76,653,757	67,207,997	16,301,558	83,509,555	106,424,504	18,735,370	125,159,874
Taxes	Francs	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Passengers Carried	Number	421,439	2,199,319	4,188,614	7,412,361	14,134,356	43,032,882	64,228,892	18,160,376	82,389,268	123,710,046	15,428,041	139,138,087	175,312,540	17,757,122	193,069,662
Passrs. Carried 1 kilometer	Number	-	-	-	-	-	-	-	-	1,366,790,822	-	-	2,688,246,288	-	-	4,306,208,193
Avg. Receipts per Passr. km.	Centimes	-	-	-	-	-	-	-	-	3.29	-	-	2.55	-	-	2.39
Tons Carried	Metric Tons	-	102,154	1,238,886	3,678,002	7,614,333	18,812,311	26,833,678	16,155,834	42,989,512	41,062,742	14,045,176	55,107,918	58,086,805	18,089,072	76,175,877
Tons Carried 1 kilometer	Metric Tons	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Avg. Receipts per ton km.	Cts. per Met. Ton	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3.81
Employees	Number	-	-	-	-	-	-	41,319	10,735	52,054	62,134	5,535	67,669	69,168	4,718	73,886

*Kilometers in operation.

TABLE XI

BRAZIL

		1900	1908		
Item	Unit	All Railways	State Railways	Private Railways	Total
Length of Line	Kilometer	9,241	-	-	19,241
Locomotives	Number	938	856	288	1,144
Passenger Train Cars	Number	1,159	1,207	407	1,614
Freight and Other Cars	Number	12,381	8,365	6,020	14,385
Total Operating Revenue	Milreis	84,315,020	56,846,292	46,839,655	103,685,947
Total Operating Expense	Milreis	65,615,905	50,595,695	31,611,488	82,207,183
Net Operating Revenue	Milreis	18,699,115	6,250,597	15,228,167	21,478,764
Passengers Carried	Number	20,541,448	26,340,932	4,822,966	31,163,898
Passrs. Carried 1 kilometer	Number	594,569,608	592,598,918	144,494,912	737,093,830
Avg. Receipts per Passr. Km.	Reis	29	27	43	30
Tons Carried	Metric Tons	-	2,484,813	2,961,086	5,445,899
Tons Carried 1 Kilometer	Metric Tons	458,626,560	440,521,270	277,652,601	718,173,871
Avg. Receipts per Ton Km.	Reis	141	89	142	109
Avg. Number of Employees	Number	27,642	24,136	11,120	35,256

TABLE XII

CANADA

		1842	1850	1860	1870	1880			1890			1900			1910		
Item	Unit	Private Railways	Private Railways	Private Railways	Private Railways	State Railways	Private Railways	Total	State Railways	Private Railways	Total	State Railways	Private Railways	Total	State Railways	Private Railways	Total
Length of Line	Miles	16.00	71.00	2,087.00	2,497.00	1,038	5,753	6,891	1,182	12,074	13,256	1,511	16,146	17,657	2,044	22,687	24,731
Length of Second Track	Miles	-	-	-	-	-	-	-	-	-	-	-	-	-	25	1,518	1,543
Total Capital	Dollars	-	-	-	-	41,858,527	328,987,283	370,815,810	57,347,826	729,099,985	786,447,813	64,185,079	934,418,559	998,603,638	118,018,751	1,601,050,750	1,719,069,501
Stocks	Dollars	-	-	-	-	-	189,956,177	189,956,177	-	338,177,386	338,177,386	-	410,326,095	410,326,095	-	687,557,387	687,557,387
Bonds	Dollars	-	-	-	-	-	80,661,316	80,661,316	-	269,728,826	269,728,826	-	381,181,827	381,181,827	-	722,740,300	722,740,300
Government Aid-Private Railways	Dollars	-	-	-	-	-	58,339,790	58,339,790	-	121,193,773	121,193,773	-	142,910,637	142,910,637	-	190,753,063	190,753,063
Locomotives	Number	-	-	-	-	129	1,028	1,157	214	1,577	1,771	249	2,033	2,282	475	3,604	4,079
Total Passenger Train Cars	Number	-	-	-	-	144	1,026	1,170	265	1,753	2,018	357	2,461	2,818	536	3,784	4,320
Freight Cars	Number	-	-	-	-	3,308	20,771	24,079	6,584	43,474	50,058	7,812	59,706	67,518	13,373	114,988	128,361
Total Operating Revenue	Dollars	13,650	-	6,839,409	13,451,289	1,620,149	21,941,298	23,561,447	3,173,712	43,670,114	46,843,826	4,774,162	65,966,108	70,740,270	11,636,186	162,320,031	173,956,217
Total Operating Expense	Dollars	10,744	-	-	-	1,770,060	15,070,645	16,840,705	3,827,062	29,086,288	32,913,350	4,665,228	43,034,570	47,699,798	10,464,533	109,940,907	120,405,440
Net Operating Revenue	Dollars	2,906	-	-	-	149,911*	6,870,653	6,720,742	653,350*	14,583,826	13,930,476	108,934	22,931,538	23,040,472	1,171,653	52,379,124	53,550,777
Taxes Paid	Dollars	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1,792,649
Passengers Carried	Number	27,041	-	1,922,227	-	672,016	6,790,932	7,462,948	1,352,332	11,468,930	12,821,262	1,939,225	19,560,950	21,500,175	4,322,840	31,571,735	35,894,575
Passengers Carried 1 Mile	Number	-	-	-	-	-	-	-	-	-	-	-	-	-	190,919,157	2,275,810,507	2,466,729,644
Receipts per Passenger Mile	Cents	-	-	-	-	-	-	-	-	-	-	-	-	-	1.804	1.871	1.866
Tons Carried (short tons)	Number	7,716	-	-	-	599,132	9,339,726	9,938,858	1,420,423	19,367,046	20,787,469	2,213,455	33,732,728	35,946,183	4,847,178	69,635,688	74,482,866
Tons Carried 1 Mi.(Short tons)	Number	-	-	-	-	-	-	-	-	-	-	-	-	-	1,175,386,371	14,536,741,330	15,712,127,701
Receipts per Ton Mile	Cents	-	-	-	-	-	-	-	-	-	-	-	-	-	0.618	0.748	0.739
Total Employees	Number	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	123,768
Aggregate Compensation of Employes	Dollars	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	67,167,793

*Deficit

TABLE XIII

DANISH STATE RAILWAYS

Item	Unit	1864	1870	1880	1890	1900	1910
Length of Line	Kilometers	97	495	855	1,530	1,800	1,951
Length of Second Track	Kilometers	-	-	-	-	158	174
Capital	Kronor	-	-	-	-	-	235,649,848
Locomotives	Number	-	-	113	255	432	604
Passenger Train Cars	Number	-	-	328	968	1,399	1,815
Freight and Other Cars	Number	-	-	1,524	3,862	5,522	8,681
Total Operating Revenue	Kronor	251,626	1,913,956	5,135,424	14,798,222	26,075,537	44,054,873
Total Operating Expense	Kronor	163,768	1,412,428	4,001,822	12,192,120	23,476,658	41,163,895
Net Operating Revenue	Kronor	87,858	501,528	1,133,602	2,606,102	2,598,879	2,890,978
Passengers Carried	Number	-	-	2,614,480	8,970,301	17,331,500	21,935,030
Passrs.Carried 1 Kilometer	Number	-	-	82,446,165	260,181,604	546,082,680	789,798,855
Receipts per Passr.-Km.	Ore	-	-	-	2.9	2.3	2.5
Tons Carried (Metric Tons)	Number	-	-	949,558	1,537,868	3,328,104	4,885,888
Tons Carried 1 Kilometer	Number	-	-	74,635,755	108,348,130	266,977,518	417,249,844
Receipts per Ton-Km.	Ore	-	-	-	6.0	4.5	5.0
Avg.Number of Employees	Number	-	1,074	2,312	6,272	9,962	12,716
In addition to the above the following kilometers of railway are privately owned		-	103	143	166	895	1,459

TABLE XIV.
EGYPTIAN STATE RAILWAYS.

TABLE XV.
FRANCE.

TABLE XIV

E G Y P T I A N S T A T E R A I L W A Y S

Item	Unit	1890	1900	1910
Length of Line	Kilometer	1,547	2,237	2,340
Length of Second Track	Kilometer	268	290	-
Locomotives	Number	249	385	-
Passenger Train Cars	Number	534	679	-
Freight and Other Cars	Number	4,261	6,984	-
Total Operating Revenue	Egyptian Pounds	1,408,542	2,214,327	3,400,066
Total Operating Expense	Egyptian Pounds	610,124	1,026,945	1,973,229
Net Operating Revenue	Egyptian Pounds	798,418	1,187,382	1,426,837
Passengers Carried	Number	4,696,286	12,822,069	25,727,045
Tons Carried	Metric Tons	*38,371,312	3,046,475	3,856,493

*Cantars

TABLE XV

F R A N C E

Item	Unit	1841 All Railways	1850 All Railways	1860 All Railways	1870 All Railways	1880 All Railways
Length of Line	Kilometers	573.00	3,010.00	9,439.00	17,440.00	23,729
Length of Second Track	Kilometers	-	-	-	7,848.00	9,482
Cost of Construction	Francs	-	-	-	7,793,125,880	10,185,021,864
Locomotives	Number	-	-	-	4,933	6,893
Passenger Train Cars	Number	-	-	-	16,651	21,905
Freight Cars	Number	-	-	-	122,921	182,089
Total Operating Revenue	Francs	12,972,366	95,618,168	418,287,341	634,363,983	1,034,923,252
Total Operating Expense	Francs	8,298,329	44,764,689	187,879,823	313,035,779	515,555,020
Net Operating Revenue	Francs	4,674,037	50,853,479	230,407,518	321,328,204	519,368,232
Total Taxes	Francs	305,600	1,907,049	20,831,176	34,414,809	81,098,319
Passengers Carried	Number	6,378,666	18,741,415	56,528,613	102,597,839	165,105,603
Passrs. Carried 1 Kilometer	Number	112,602,286	-	2,521,201,667	4,272,346,298	5,862,602,096
Receipts per Passr. Km.	Centimes	7.00	-	5.64	4.95	5.04
Tons Carried (Metric)	Number	1,059,793	4,271,057	23,137,769	37,065,775	80,773,680
Tons Carried 1 Kilometer	Number	38,768,850	-	3,119,946,899	5,056,960,270	10,350,209,739
Receipts per ton - Km.	Centimes	12.00	-	6.92	6.14	5.95
Total Employees	Number	-	-	-	128,398	204,702

Item	1890 State Railways	1890 Private Railways	1890 Total	1900 State Railways	1900 Private Railways	1900 Total	1910 State Railways	1910 Private Railways	1910 Total
Length of Line	2,530	31,019	33,549	2,783	35,261	38,040	8,900	31,538	40,438
Length of Second Track	302	13,330	13,632	571	15,538	16,109	2,934	14,777	17,711
Cost of Construction	705,727,942	13,537,630,329	14,243,358,271	-*	-*	-*	3,640,538,061	15,233,410,324	18,870,948,385
Locomotives	528	9,049	9,577	587	9,942	10,529	2,504	10,336	12,840
Passenger Train Cars	2,727	32,054	34,781	3,080	40,377	43,457	11,705	38,542	50,247
Freight Cars	13,113	231,448	244,561	13,110	259,535	272,645	48,209	280,725	328,934
Total Operating Revenue	36,097,756	1,099,094,260	1,135,192,016	50,187,070	1,466,652,057	1,516,839,127	289,685,984	1,537,482,473	1,827,168,457
Total Operating Expense	24,972,447	558,033,727	583,006,174	36,132,407	788,023,258	824,155,665	233,387,196	865,414,715	1,098,801,911
Net Operating Revenue	11,125,309	541,060,533	552,185,842	14,054,663	678,628,799	692,683,462	56,298,788	672,067,758	728,366,546
Total Taxes	13,037,825	299,319,952	312,357,777	8,740,839	244,823,608	253,564,447	53,030,751	252,764,825	305,795,576
Passengers Carried	8,686,986	232,431,720	241,118,706	12,722,147	430,470,675	443,192,822	127,243,801	381,314,386	508,558,187
Passrs. Carried 1 Kilometer	358,481,014	7,584,478,635	7,942,959,649	577,355,540	13,485,662,938	14,063,018,478	3,464,873,505	13,442,052,832	16,906,926,337
Receipts per Passr. Km.	3.51	4.44	4.40	2.99	3.70	3.68	3.16	3.54	3.46
Tons Carried (Metric)	2,760,253	89,745,665	92,505,918	3,906,955	122,922,768	126,829,723	19,830,832	153,410,651	173,241,483
Tons Carried 1 Kilometer	306,767,457	11,452,316,631	11,759,084,088	439,447,480	16,117,740,748	16,557,188,228	2,311,980,608	19,672,008,090	21,983,988,698
Receipts per ton - Km.	5.57	5.44	5.45	5.26	4.68	4.69	5.20	4.17	4.27
Total Employees	10,790	222,209	232,999	12,446	274,331	286,777	70,966	268,066	339,032

*Not Reported.

TABLE XVI

G E R M A N Y

Item	Unit	1880			1890			1900			1910		
		Standard and Narrow Gauge Railways, either Owned or Operated by the State	Private Railways (Standard and Narrow Gauge)	Totals	Standard and Narrow Gauge Railways, either Owned or Operated by the State	Private Railways (Standard and Narrow Gauge)	Totals	Standard and Narrow Gauge Railways, either Owned or Operated by the State	Private Railways (Standard and Narrow Gauge)	Totals	Standard and Narrow Gauge Railways, either Owned or Operated by the State	Private Railways (Standard and Narrow Gauge)	Totals
Length of Line	Kilometer	26,218.09	7,682.21	33,900.30	38,541.25	4,388.76	42,930.01	46,681.71	5,048.15	51,729.86	56,755.01	4,682.91	61,437.92
Length of Second Track	Kilometer	8,115.13	1,813.75	9,928.88	11,880.16	829.74	12,709.90	17,263.85	706.05	17,969.90	22,783.27	101.09	22,884.36
Length of Third Track	Kilometer	36.48	-	36.48	66.66	-	66.66	160.78	8.72	169.50	347.07	-	347.07
Length of Fourth Track	Kilometer	3.87	-	3.87	23.01	-	23.01	108.81	8.72	117.53	266.61	-	266.61
Length of Fifth Track	Kilometer	-	-		-	-		-	-	-	5.06	-	5.06
Capital	Marks	7,399,175,663	1,491,157,667	8,890,333,330	9,811,034,930	699,323,427	10,510,358,357	12,231,327,221	616,807,791	12,848,135,012	17,084,735,977	433,608,336	17,518,344,313
Locomotives	Number	9,000	1,906	10,906	13,471	931	14,402	18,382	1,080	19,462	26,778	884	27,662
Passenger Train Cars	Number	17,089	4,154	21,243	26,388	2,189	28,577	39,094	2,706	41,800	59,438	2,200	61,638
Freight and Other Cars	Number	189,657	36,074	225,731	273,391	18,732	292,123	396,658	23,809	420,467	580,135	12,853	592,988
Total Operating Revenue	Marks	725,010,672	161,964,360	886,975,032	1,235,050,068	72,366,366	1,307,416,434	1,956,903,668	83,740,349	2,040,644,017	2,991,767,680	58,721,169	3,050,488,849
Total Operating Expense	Marks	396,497,099	90,607,656	487,104,755	755,346,509	40,552,311	795,898,820	1,228,774,564	53,825,522	1,282,600,086	2,014,223,267	38,140,442	2,052,363,709
Net Operating Revenue	Marks	328,513,573	71,356,704	399,870,277	479,703,559	31,814,055	511,517,614	728,129,104	29,914,827	758,043,931	977,544,413	20,580,727	998,125,140
Taxes	Marks	5,079,112	2,535,915	7,615,027	8,677,266	1,055,357	9,732,623	14,716,848	1,481,985	16,198,833	21,346,448	1,256,131	22,602,579
Passengers Carried	Number	172,225,310	42,992,318	215,217,628	395,123,385	39,014,529	434,137,914	817,531,385	61,688,750	879,220,135	1,503,540,368	68,991,060	1,572,531,428
Passrs. Carried 1 Km.	Number	5,242,649,599	1,238,221,678	6,480,871,277	10,606,755,351	679,262,902	11,286,018,253	19,444,723,437	805,467,614	20,250,191,051	34,867,954,211	809,829,971	35,677,784,182
Avg. Receipts per Passr. Km.	Pfennig	3.46	3.58	3.47	3.12	3.27	3.13	2.74	2.98	2.75	2.35	2.74	2.36
Tons Carried	Metric Tons	131,380,845	29,008,831	160,389,676	199,640,838	19,710,791	219,351,629	316,691,029	28,370,234	345,061,263	511,782,925	29,934,413	541,717,338
Tons Carried 1 Km.	Metric Tons	10,941,705,161	2,133,257,581	13,074,962,742	21,343,886,880	933,021,070	22,276,907,950	33,658,576,166	1,120,907,274	34,779,483,440	51,490,585,052	444,950,130	51,935,535,182
Avg. Receipts per ton-Km.	Pfennig per metric ton	4.32	4.75	4.41	3.84	4.49	3.86	3.65	3.97	3.66	3.65	6.10	3.67
Avg. Number of employees	Number	230,856	54,028	284,884	379,886	21,467	401,353	518,236	22,742	540,978	692,579	13,945	706,524
Compensation of employees	Marks	236,382,982	51,530,313	287,913,295	446,106,022	23,351,762	469,457,784	670,100,012	27,595,780	697,695,792	1,122,667,534	18,610,509	1,141,278,043

TABLE XVII

I N D I A

Item	Unit	1862	1870	1878	1890	1900	1910
		All Railways	All Railways	All Railways	All Railways	All Railways	All Railways
Length of Line	Miles	15	36	7,143	16,095	24,707	32,099
Length of Second Track	Miles	-	-	803	-	-	-
Capital	Rupee			£113,344,541	2,050,460,994	3,303,483,361	4,390,473,000
Locomotives	Number	-	-	1,630	3,662	-	7,245
Passenger Train Cars	Number	-	-	4,894	9,940	-	20,372
Freight Cars	Number	-	-	29,263	69,185	-	149,628
Total Operating Revenue	Rupee	-	-	£ 11,236,121	204,936,629	315,967,000	511,422,000
Total Operating Expense	Rupee	-	-	£ 5,003,233	103,774,007	150,995,000	271,572,000
Net Operating Expense	Rupee	-	-	£ 6,232,888	101,162,622	164,972,000	239,850,000
Passengers Carried	Number	-	-	34,143,512	110,650,472	174,824,483	371,576,000
Passrs. Carried 1 mile	Number	-	-	920,751,905	4,676,868,296	7,008,713,000	13,432,477,000
Receipts per Passr. Mi.	Pies	-	-	Pence 0.337	2.5	2.5	2.45
Tons Carried (long ton)	Number	-	-	8,309,943	22,249,111	43,615,289	65,603,000
Tons Carried 1 mile	Number	-	-	1,941,287,686	3,643,797,257	6,698,000,000	12,092,916,000
Receipts per ton mile	Pies	-	-	Pence 0.932	6.8	5.85	4.83
Employees	Number	-	-	132,040	238,217	350,177	543,493

TABLE XVIII

I T A L Y

		1870			1880			1890			1900			1910		
Item	Unit	State Railways	Private Railways	Total	State Railways	Private Railways	Total	State Railways	Private Railways	Total	State Railways	Private Railways	Total	State Railways	*Private Railways	Total
Length of Line	Kilometer	804	5,356	6,160	3,830	4,769	8,599	8,421	4,434	12,855	-	-	15,884	13,348	3,620	16,968
Capital	Lire	-	-	1,785,000,000	-	-	2,616,737,800	-	-	-	-	-	5,381,147,053	6,390,000,000	550,000,000	6,940,000,000
Locomotives	Number	-	-	-	-	-	-	-	-	-	-	-	3,067	4,826	550	5,376
Passenger Train Cars	Number	-	-	-	-	-	-	-	-	-	-	-	8,697	10,852	1,650	12,502
Freight and Other Cars	Number	-	-	-	-	-	-	-	-	-	-	-	54,365	90,759	5,400	96,159
Total Operating Revenue	Lire	-	-	99,343,358	-	-	180,106,819	-	-	255,687,108	-	-	318,366,324	535,220,821	33,000,000	568,220,821
Total Operating Expense	Lire	-	-	63,760,000	-	-	122,262,862	-	-	173,379,424	-	-	239,516,399	443,739,631	26,000,000	469,739,631
Net Operating Revenue	Lire	-	-	35,583,358	-	-	57,843,957	-	-	82,307,684	-	-	78,849,925	91,481,190	7,000,000	98,481,190
Passengers Carried	Number	-	-	22,170,000	-	-	32,491,827	-	-	50,855,569	-	-	59,695,420	82,407,600	28,000,000	110,407,600
Tons Carried	Metric Tons	-	-	4,757,000	-	-	9,329,073	-	-	16,483,651	-	-	17,996,331	33,943,640	4,500,000	38,443,640
Avg. Number of Employees	Number	-	-	-	-	-	-	-	-	-	-	-	-	150,000	12,000	162,000
Compensation of Employees	Lire	-	-	-	-	-	-	-	-	-	-	-	-	245,000,000	13,700,000	258,700,000

*Approximate.

TABLE XIX

J A P A N

		1873	1880	1890			1900			1910		
Item	Unit	State Railways	State Railways	State Railways	Private Railways	Total	State Railways	Private Railways	Total	State Railways	Private Railways	Total
Length of Line	Miles	18.00	73.22	550.49	585.85	1,136.34	832.72	2,806.00	3,638.72	4,623.61	506.05	5,129.66
Length of Second Track	Miles	-	-	-	-	-	158.15	92.39	250.54	629.33	-	629.33
Length of Third Track	Miles	-	-	-	-	-	-	-	-	4.97	-	4.97
Length of Fourth Track	Miles	-	-	-	-	-	-	-	-	4.57	-	4.57
Capital	Yen	-	-	-	-	-	69,979,049	177,029,493	247,008,542	784,963,769	34,331,457	819,295,226
Locomotives	Number	-	-	-	-	-	343	871	1,214	2,174	131	2,305
Passenger Train Cars	Number	-	-	-	-	-	1,022	3,129	4,151	5,433	716	6,144
Freight Cars	Number	-	-	-	-	-	3,683	12,822	16,505	33,665	1,574	35,239
Total Operating Revenue	Yen	174,930	1,243,531	3,771,630	2,453,007	6,224,637	13,719,006	24,850,648	38,569,654	82,236,436	4,180,227	86,416,663
Total Operating Expense	Yen	113,464	512,674	1,663,417	1,025,804	2,689,221	6,596,677	12,234,947	18,831,624	42,060,969	2,142,241	44,203,230
Net Operating Revenue	Yen	61,466	730,857	2,108,213	1,427,203	3,535,416	7,122,329	12,615,701	19,738,030	40,175,447	2,037,986	42,213,433
Passengers Carried	Number	-	-	-	-	-	28,663,683	73,452,259	102,115,942	128,306,960	24,781,106	153,088,066
Passengers Carried 1 Mi.	Number	-	-	-	-	-	635,044,513	1,076,805,648	1,711,850,161	2,812,329,108	188,424,281	3,000,753,389
Receipts per Passr. Mi.	Yen	-	-	-	-	-	0.0146	0.0131	0.0137	0.0140	0.0152	0.01408
Tons Carried (Long tons)	Number	-	-	-	-	-	2,391,471	9,428,563	11,820,034	23,655,620	2,155,853	25,811,473
Tons Carried 1 mile	Number	-	-	-	-	-	177,318,088	422,152,648	599,470,736	1,911,197,440	30,856,076	1,942,053,516
Receipts per ton-mile	Yen	-	-	-	-	-	0.0210	0.0213	0.0212	0.0165	0.0257	0.01664
Employees	Number	-	-	-	-	-	19,881	33,903	53,784	90,131	4,463	94,594
Compensation of employes	Yen	-	-	-	-	-	3,366,120	4,998,948	8,365,068	18,925,872	740,688	19,666,560

TABLE XX

NETHERLANDS

Item	Unit	1873			1880			1890			1900			1910
		State Railways	Private Railways	Total	State Railways	Private Railways	Total	State Railways	Private Railways	Total	State Railways	Private Railways	Total	All Railways
Length of Line	Kilometers	869	463	1,332	1,199	1,124	2,323	1,565	1,097	2,662	1,718	1,526	3,244	3,623
Length of Second Track	Kilometers	-	281	281	127	354	481	-			-	-	-	1,469
Capital	Gulden	96,404,502	80,875,974	177,280,476	152,428,908	107,425,016	259,853,924	258,271,000	-	-	-	-	-	-
Locomotives	Number	-	-	-	-	-	-	-	-	-	-	-	-	1,162
Passenger Train Cars	Number	-	-	-	-	-	-	-	-	-	-	-	-	3,014
Freight and Other Cars	Number	-	-	-	-	-	-	-	-	-	-	-	-	20,850
Total Operating Revenue	Gulden	5,089,816	8,545,889	13,635,705	9,373,545	12,804,055	22,177,600	13,749,637	9,826,328	23,575,965	23,789,256	18,863,852	42,653,108	63,493,000
Total Operating Expense	Gulden	5,406,490	5,205,135	10,611,625	5,062,592	6,123,968	11,186,560	11,806,417	7,299,967	19,106,384	20,809,000	17,083,165	37,892,165	51,857,000
Net Operating Revenue	Gulden	316,674	3,340,754	3,024,080	4,310,953	6,680,087	10,991,040	1,943,220	2,526,361	4,469,581	2,980,256	1,780,687	4,760,943	11,636,000
Passengers Carried	Number	3,435,517	5,894,024	9,329,541	5,989,897	9,999,896	15,989,793	6,664,434	10,305,900	16,970,334	12,256,609	17,761,769	30,018,378	46,221,000
Receipts per Passr.Km.	Gulden	-	-	-	-	-	-	-	-	-	-	-	.024	.022
Tons Carried (metric ton)	Number	879,013	907,116	1,786,129	2,236,600	2,200,785	4,437,385	4,378,798	2,377,206	6,756,004	7,273,688	4,385,361	11,659,049	16,051,000
Receipts per ton km.	Gulden	-	-	-	-	-	-	-	-	-	-	-	.018	.021

TABLE XXI

NEW ZEALAND

Item	Unit	1883	1890	1900	1910
Length of Line	Miles	1,358	1,809	2,104	2,717
Capital	Pounds	10,478,998	13,899,955	16,703,887	28,513,476
Locomotives	Number	-	-	-	465
Passenger Train Cars	Number	-	-	-	1,140
Freight and Other Cars	Number	-	-	-	17,220
Total Operating Revenue	Pounds	953,347	1,095,570	1,623,891	3,249,790
Total Operating Expense	Pounds	592,821	682,787	1,052,358	2,169,474
Net Operating Revenue	Pounds	360,526	412,783	571,533	1,080,316
Passengers Carried	Number	3,283,378	3,376,459	5,468,284	11,141,142
Tons Carried	Long Tons	1,564,823	2,073,955	3,127,874	5,223,414
Avg.Number of Employees	Number	-	-	-	12,224

TABLE XXII

NORWAY

Item	Unit	1855 All Railways	1860 All Railways	1870 All Railways	1880 State Railways	1880 Private Railways	1880 Total	1890 State Railways	1890 Private Railways	1890 Total	1900 State Railways	1900 Private Railways	1900 Total	1910 State Railways	1910 Private Railways	1910 Total
Length of Line	Kilometer	68	68	359	989	68	1,057	1,494	68	1,562	1,879	178	2,057	2,506	470	2,976
Length of Second Track	Kilometer	-	-	-	-	-	-	-	-	-	-	-	-	354	130	484
Capital	Kroner	8,726,000	9,068,000	26,019,000	69,961,323	10,032,558	79,993,881	117,237,380	10,949,897	128,187,277	156,279,946	16,033,735	173,313,681	250,469,148	37,376,881	287,846,029
Locomotives	Number	-	-	-	75	16	91	124	22	146	195	47	242	-	-	362
Passenger Train Cars	Number	-	-	-	334	44	378	460	58	518	471	83	554	-	-	865
Freight and Other Cars	Number	-	-	-	1,712	450	2,162	2,761	556	3,317	5,006	1,199	6,205	-	-	7,782
Total Operating Revenue	Kroner	480,000	678,000	1,868,000	3,216,791	1,086,942	4,303,733	7,330,050	1,697,057	9,017,107	12,420,912	2,765,012	15,185,924	19,615,943	3,846,212	23,462,155
Total Operating Expense	Kroner	321,000	321,000	1,219,000	2,682,383	607,014	3,289,397	5,117,925	806,773	5,924,698	10,005,960	2,046,836	12,052,796	14,623,546	2,889,915	17,513,461
Net Operating Revenue	Kroner	159,000	240,000	649,000	534,408	479,928	1,014,336	2,202,125	890,284	3,092,409	2,414,952	718,176	3,133,128	4,992,397	956,297	5,948,694
Passengers Carried	Number	128,000	152,000	551,000	1,395,606	252,477	1,648,083	3,735,390	389,598	*3,989,447	9,126,081	1,078,898	*9,899,535	11,703,183	1,846,662	*13,079,037
Passrs.Carried 1 Kilometer	Number	-	4,782,000	17,294,000	42,753,241	7,891,108	50,644,349	95,393,429	11,464,468	106,857,897	207,125,829	27,346,800	234,472,629	294,635,627	40,763,191	335,398,818
Avg.Receipts per Passr.Km.	Ore	-	3.3	2.6	-	3.4	3.3	3.2	3.1	3.2	2.7	-	2.8	2.8	2.8	2.8
Tons Carried	Number	83,000	144,000	350,000	301,445	303,937	605,382	1,057,509	495,910	*1,325,770	1,815,497	926,749	*2,307,219	4,198,976	1,260,315	*4,889,339
Tons Carried 1 Kilometer	Metric Tons	-	5,027,000	19.953,000	28,754,759	9,569,902	38,324,661	72,875,782	16,143,356	89,019,138	124,912,493	28,912,971	153,825,464	256,150,872	37,326,872	293,477,744
Avg.Receipts per ton-Km.	Ore per Met.Ton	-	9.4	6.3	-	7.6	5.6	4.7	7.4	5.2	4.3	-	4.6	3.6	6.4	4.2
Avg.Number of Employees	Number	-	-	-	1,368	326	1,694	-	-	-	-	-	-	-	-	5,949

*As Reported.

TABLE XXIII

PORTUGAL

Item	Unit	1880 State Railways	1880 Private Railways	1880 Total	1890 State Railways	1890 Private Railways	1890 Total	1900 State Railways	1900 Private Railways	1900 Total	1910 State Railways	1910 Private Railways	1910 Total
Length of Line	Kilometer	594	550	1,144	828	1,104	1,932	843	1,325	2,168	1,024	1,424	2,448
Total Operating Revenue	Milreis	*5,627,000	*11,011,000	*16,638,000	1,585,227	3,830,224	5,415,451	2,116,021	5,530,584	7,646,605	3,204,688	7,385,572	10,590,260
Total Operating Expense	Milreis	-	-	-	910,271	1,647,954	2,558,225	1,125,041	2,393,705	3,518,746	1,884,876	3,247,548	5,132,424
Net Operating Revenue	Milreis	-	-	-	674,956	2,182,270	2,857,226	990,980	3,136,879	4,127,859	1,319,812	4,138,024	5,457,836
Passengers Carried	Number	971,053	1,153,101	2,124,154	1,241,204	3,973,977	5,215,181	1,760,195	9,149,166	10,909,361	2,911,104	11,977,603	14,888,707
Tons Carried	Metric Tons	253,285	378,131	631,416	413,683	1,812,123	2,225,806	694,859	1,870,570	2,565,429	1,185,487	3,659,326	4,844,813

*Francs

TABLE XXIV

ROUMANIA

Item	Unit	1901	1910
Length of Line	Kilometers	3,100	3,186
Capital	Lei	-	987,170,467
Total Operating Revenue	Lei	50,158,165	84,430,822
Total Operating Expense	Lei	35,645,927	53,231,141
Net Operating Revenue	Lei	14,512,238	31,199,681
Passengers Carried	Number	5,472,038	9,169,849
Tons Carried(Metric Tons)	Number	3,987,641	6,966,277
Avg.Receipts per ton-km.	Lei per Metric Ton-Km.	-	.0447

TABLE XXV

RUSSIA

Item	Unit	1890			1900			1910		
		State Railways	Private Railways	Total	State Railways	Private Railways	Total	State Railways	Private Railways	Total
Length of Line	Versts	8,030.83	19,407.29	27,438.12	33,569	15,612	49,181	42,025.31	21,048.20	63,073.51
Length of Double or more tracks	Versts	105.38	4,316.65	4,422.03	7,663	1,783	9,446	11,238.52	2,580.64	13,819.16
Capital	Rubles	463,270,706	1,560,496,434	2,023,767,140	3,382,043,017	1,142,374,967	4,524,417,984	4,951,405,205	1,918,206,369	6,875,611,574
Locomotives	Number	1,535	5,398	6,933	8,840	3,497	12,337	15,264	5,025	20,289
Passenger Train Cars	Number	1,596	6,402	7,998	11,936	4,515	16,451	20,400	6,347	26,747
Freight and Other Cars	Number	33,150	112,461	145,611	199,698	91,048	290,746	327,991	127,186	455,177
Total Operating Revenue	Rubles	51,544,495	232,986,143	284,530,638	410,332,464	172,299,236	582,631,700	664,517,268	313,429,225	977,946,493
Total Operating Expense	Rubles	32,753,490	139,020,792	171,774,282	274,699,014	110,220,985	384,919,999	468,064,341	189,243,795	657,308,136
Net Operating Revenue	Rubles	18,791,005	93,965,351	112,756,356	135,633,450	62,078,251	197,711,701	196,452,927	124,459,361	320,912,288
Passengers Carried	Number	7,108,915	39,395,760	46,504,675	76,731,683	30,268,581	107,000,264	142,607,697	65,502,624	208,110,321
Passengers Carried 1 verst	Number	790,132,000	3,909,502,000	4,699,634,000	8,065,546,200	2,902,998,600	10,968,544,800	14,450,326,200	5,144,391,900	19,594,718,100
Avg.Receipts per Passr.-verst	Copecks	.93	1.08	1.05	.90	.88	.90	.84	.96	.90
Poods Carried	Number	714,911,925	3,464,500,419	4,179,412,344	6,708,655,453	2,700,109,215	9,408,764,668	10,154,730,395	4,379,875,347	14,534,605,742
Poods Carried 1 verst	Number	172,028,925,000	682,006,669,000	854,035,594,000	836,631,848,210	342,261,567,790	1,178,893,416,000	1,276,410,886,300	561,154,228,000	1,837,565,114,000
Avg.Receipts per Pood - verst	Copecks	.023	.024	.0243	.0204	.0213	.0208	.0213	.0222	.0217
Average number of employees	Number	53,928	198,487	252,415	390,073	164,295	554,368	565,435	211,295	776,730
Compensation of employees	Rubles	17,200,[illegible]	64,350,136	81,550,268	131,212,634	51,873,369	183,086,003	233,384,915	86,143,131	319,528,046

TABLE XXVI

S P A I N

Item	Unit	1871	1880	1890	1900	1909
Length of Line	Kilometer	5,487	7,330	10,002	13,214	14,607
Capital	Pesetas	-	-	-	-	3,782,017,950
Locomotives	Number	-	1,245	-	-	2,533
Passenger Train Cars	Number	-	3,569	-	-	6,189
Freight and Other Cars	Number	-	20,268	-	-	50,109
Total Operating Revenue	Pesetas	90,691,276	139,218,544	193,282,769	261,300,000	339,604,858
Total Operating Expense	Pesetas	39,089,085	61,313,291	86,808,453	122,000,000	166,811,599
Net Operating Revenue	Pesetas	51,602,191	77,905,253	106,474,316	139,300,000	172,793,259
Passengers Carried	Number	11,501,129	-14,812,851	25,809,006	32,000,000	51,408,194
Passers.Carried 1 Km.	Number	-	-	-	-	1,889,691,320
Tons Carried	Metric Tons	3,737,858	8,088,175	-	-	31,456,774
Tons Carried 1 Km.	Metric Tons	-	-	-	-	3,085,518,819

TABLE XXVII

S W E D E N

		1870			1880			1890			1900			1910		
Item	Unit	State Railways	Private Railways	Total	State Railways	Private Railways	Total	State Railways	Private Railways	Total	State Railways	Private Railways	Total	State Railways	Private Railways	Total
Length of Line	Kilometer	1,117	627	1,744	1,956	3,926	5,882	2,613	5,405	8,018	3,850	7,453	11,303	4,418	9,411	13,829
Capital	Kronor	91,144,959	33,228,447	124,373,406	191,389,676	227,598,207	418,987,883	255,055,498	262,492,784	517,548,282	358,409,000	367,518,000	725,927,000	522,862,294	544,988,087	1,067,850,381
Locomotives	Number	-	-	-	-	-	-	376	476	852	580	762	1,342	879	1,042	1,921
Passenger Train Cars	Number	-	-	-	-	-	-	900	1,071	1,971	1,062	1,532	2,594	1,528	2,103	3,631
Freight and Other Cars	Number	-	-	-	-	-	-	9,301	11,588	20,889	14,378	19,035	33,413	21,557	25,710	47,267
Total Operating Revenue	Kronor	6,791,193	3,969,284	10,760,477	16,490,000	16,019,084	32,509,084	21,972,575	25,426,204	47,398,779	44,626,002	45,671,924	90,297,926	72,131,021	69,930,756	142,061,777
Total Operating Expense	Kronor	3,610,677	1,817,527	5,428,204	9,983,205	7,973,781	17,956,986	15,272,372	13,027,383	28,299,755	33,974,804	28,682,631	62,657,435	56,231,490	46,645,565	102,877,055
Net Operating Revenue	Kronor	3,180,516	2,151,757	5,332,273	6,506,795	8,045,303	14,552,098	6,700,203	12,398,821	19,099,024	10,651,198	16,989,293	27,640,491	15,899,531	23,285,191	39,184,722
Passengers Carried	Number	1,593,141	891,030	2,484,171	3,204,830	3,813,934	7,018,764	4,702,688	7,991,102	12,693,790	10,948,822	19,881,941	30,830,763	20,500,440	37,776,210	58,276,650
Passrs.Carried 1 Kilometer	Number	-	-	-	-	-	-	206,532,807	176,568,679	383,101,486	454,430,823	368,256,617	822,687,440	846,083,400	728,429,700	1,574,513,100
Avg.Receipts per Passenger-Km.	Ore	-	-	-	-	-	-	-	-	-	-	-	3.60	2.73	3.03	2.87
Tons Carried	Metric Tons	712,505	1,370,511	2,083,016	1,828,241	4,060,771	5,889,012	3,188,089	7,419,636	10,607,725	6,719,441	14,923,457	21,642,898	13,137,820	23,852,810	36,990,630
Tons Carried 1 kilometer	Metric Tons	-	-	-	-	-	-	319,677,987	311,199,691	630,877,678	93,539,900	665,272,200	1,458,812,100	1,590,610,300	1,074,253,200	2,664,863,500
Avg.Receipts per ton-Km.	Ore per Met.Ton	-	-	-	-	-	-	-	-	-	-	-	3.91	3.13	4.23	3.59

TABLE XXVIII

S W I T Z E R L A N D

Item	Unit	1870	1880	1890	1900	1910
Length of Line	Kilometer	1,365.6	2,563.1	3,100.9	3,707.1	4,572.5
Length of Second Track	Kilometer	-	-	480.6	731.6	1,020.7
Capital	Francs	453,008,093	747,350,802	957,669,588	1,233,485,809	1,767,919,135
Locomotives	Number	247	543	757	1,198	1,602
Passenger Train Cars	Number	894	1,655	2,062	2,895	4,611
Freight and Other Cars	Number	3,703	8,553	9,789	13,797	17,907
Total Operating Revenue	Francs	32,963,499	60,020,371	92,795,189	142,099,023	222,437,673
Total Operating Expense	Francs	16,585,951	31,497,203	51,066,254	83,572,800	140,570,421
Net Operating Revenue	Francs	16,377,548	28,523,168	41,728,935	58,526,223	81,867,252
Passengers Carried	Number	10,773,234	21,608,581	32,378,357	62,800,212	110,068,465
Passengers Carried 1 Km.	Number	193,028,930	447,218,678	701,779,485	1,239,007,614	2,312,931,954
Avg.Receipts per Passr.Km.	Centimes	4.99	5.27	5.27	4.83	4.15
Tons Carried	Metric Tons	2,574,800	5,817,008	9,389,847	14,591,416	17,023,916
Tons Carried 1 Km.	Metric Tons	105,547,114	295,571,317	560,211,070	805,909,276	1,248,826,595
Avg.Receipts per ton-Km.	Cts.per Met.Ton	10.71	10.73	9.11	9.31	9.37
Avg.Number of Employees	Number	-	13,248	19,679	28,674	41,179
Compensation of Employees	Francs	-	14,408,552	22,366,026	38,549,442	69,462,774

TABLE XXIX

U N I T E D K I N G D O M

		1850	1860	1870	1880	1890	1900	1910
Item	Unit	All Railways	All Railways	All Railways	All Railways	All Railways	All Railways	All Railways
Length of Line	Miles	6,621	10,433	15,537	17,933	20,073	21,855	23,389
Length of Second Track	Miles	**5,466	**6,690	**8,200	**9,803	**10,989	**12,162	13,189
Length of Third Track	Miles	-	-	-	-	-	-	1,517
Length of Fourth Track	Miles	-	-	-	-	-	-	1,192
Length of Fifth or More Track	Miles	-	-	-	-	-	-	564
Capital Paid Up	Pounds	240,270,745	348,150,127	529,908,673	728,316,848	897,472,026	1,176,001,890	1,318,515,417
Stocks	Pounds	184,763,677	258,664,707	387,974,234	546,558,217	664,959,156	865,458,329	964,337,470
Loans and Debenture Bonds	Pounds	55,507,068	89,668,420	141,934,439	181,758,631	232,512,870	310,543,561	354,177,947
Locomotives	Number	-	-	9,379	13,384	16,237	21,195	22,840
Passenger Train Cars	Number	-	-	28,160	40,851	50,881	66,017	72,815
Freight Cars	Number	-	-	261,834	391,615	540,578	709,200	766,729
Total Operating Revenue	Pounds	13,204,669	27,766,022	45,078,143	65,491,625	79,948,702	104,801,858	123,925,565
Total Operating Expense	Pounds	-	13,187,368	21,715,525	33,601,124	43,188,556	64,743,520	76,569,676
Net Operating Revenue	Pounds	-	14,579,254	23,362,618	31,890,501	36,760,146	40,058,338	47,355,889
Taxes and Rates	Pounds	-	-	926,806	-	2,251,087	3,757,153	5,102,000
*Passengers Carried	Number	72,854,422	163,435,678	336,545,397	603,885,025	817,744,046	1,142,276,686	1,306,728,583
Tons Carried (long tons)	Number	-	89,857,719	-	235,305,629	303,119,427	424,929,513	514,428,806

*Excluding season ticketholders, etc.
**Double or more track.

TABLE XXX

UNITED STATES

Item	Unit	1830	1840	1850	1860	1870	1880	1890	1900	1910
Length of Line	Miles	23	2,818	9,021	30,635	53,487	87,832	163,597	193,346	240,439
Length of Second Track	Miles	-	-	-	-	2,217	4.562	8,438	12,151	21,659
Length of Third Track	Miles	-	-	-	-	-	-	761	1,095	2,206
Length of Fourth Track	Miles	-	-	-	-	-	-	562	829	1,489
Capital	Dollars	-	-	-	-	2,782,245,675	5,004,521,666	9,437,343,420	11,491,034,960	18,417,132,238
Locomotives	Number	-	-	-	-	10,913	17,412	30,140	37,663	58,947
Passenger Train Cars	Number	-	-	-	-	10,768	16,806	26,820	34,713	47,095
Freight Cars	Number	-	-	-		239,783	455,450	1,142,847	1,416,125	2,243,236
Total Operating Revenue	Dollars			39,466,358	-	390,712,300	580,450,594	1,051,877,632	1,487,044,814	2,750,667,435
Total Operating Expense	Dollars	-	-	-		260,379,100	352,800,121	692,093,971	961,428,511	1,822,630,433
Net Operating Revenue	Dollars	-	-			130,333,200	227,650,473	359,783,661	525,616,303	928,037,002
Taxes	Dollars	-	-	-			13,283,819	31,943,020	48,332,273	103,795,701
Passengers Carried	Number	-	-		-	67,198,000	269,583,340	492,430,865	576,865,230	971,683,199
Passrs.Carried 1 mile	Number	-		-		2,101,300,976	5,740,112,502	11,847,785,617	16,039,007,217	32,338,496,329
Receipts per Passr.-mile	Cents	-	-	-	-	2.987	2.510	2.167	2.003	1.938
Tons Carried	No.Short Tons	-	-	-	-	62,240,000	290,897,395	636,541,617	593,970,955	1,026,491,782
Tons Carried 1 mile	No.Short Tons	-			-	5,295,831,217	32,348,846,693	76,207,047,298	141,599,157,270	255,016,910,451
Receipts per ton-mile	Cents	-	-	-	-	2.447	1.287	0.941	0.729	0.753
Employees	Number	-	-	-	-	-	418,957	749,301	1,017,653	1,669,420
Total Compensation of Employees	Dollars	-	-	-	-		195,350,013	433,970,343	577,264,841	1,143,725,306
Avg.Monthly Compensation of Employees	Dollars	-	-	-	-		38.86	48.30	47.40	57.30

TABLE XXXI

CONVERSION TABLE

Metric and Other Measures	Equivalent in United States Measures
1 kilometer	0.621 mile.
1 metric ton	1.102 short tons (2000 pounds
1 metric ton-kilometer ..	0.684 short ton-mile
1 long ton (2240 pounds).	1.12 short tons (2000 pounds
1 long ton-mile	1.12 short ton-mile
1 verst	0.663 mile.
1 pood	0.01806 short ton
1 pood-verst	0.01197 short ton-mile
United States Measures	**Equivalent in Metric and Other Measures**
1 short ton (2000 pounds)	0.907 metric ton 0.893 long ton 55.371 poods
1 mile	1.61 kilometers 1.51 verst
1 short ton-mile	1.46 metric ton-kilometers 0.893 long ton-mile 83.61 pood-versts

Country	Unit	Equivalent in United States Dollars
Argentina	Gold peso	0.96477
Austria-Hungary	Krone	0.20263
Belgium	Franc	0.19295
Brazil	Milreis	0.32444
Canada	Dollar	1.00000
Denmark	Krone	0.26799
Egypt	Egyptian Pound	4.94307
France	Franc	0.19295
Germany	Mark	0.23821
India	Rupee	0.3840 in 1890 0.3270 in 1900 0.3245 in 1910
Italy	Lira	0.19295
Japan	Yen	0.49846
Netherlands	Guilder	0.40196
New Zealand	Pound Sterling	4.86656
Norway	Krone	0.26799
Portugal	Milreis	1.08046
Roumania	Lei	0.19295
Russia	Rouble	0.51456
Spain	Peseta	0.19295
Sweden	Krona	0.26799
Switzerland	Franc	0.19295
United Kingdom	Pound Sterling	4.86656
United States	Dollar	1.00000

TABLE XXXII

COMPARATIVE RAILWAY STATISTICS
- 1910 -

Sheet No.1

Country	Length of Line Miles 1	Length of Second and More Tracks Miles 2	Length of Second and More Tracks per Mile of Line Miles 3	Capital Dollars 4	Capital per Mile of Line Dollars 5
Argentina	17,384.48	-	-	868,914,999	49,982
Austria-Hungary	23,499.07	4,045.50	.17	2,550,654,784	108,543
Belguim	2,932.20	1,430.00	.49	547,748,772	186,804
Brazil (1908)	11,948.66	-	-	-	-
Canada	24,731.00	1,543.00	.06	1,719,069,501	69,511
Denmark	1,211.57	108.05	.09	63,154,159	52,125
Egypt (State Rys.)	1,453.14	-	-	-	-
France	25,072.00	10,981.00	.44	3,642,093,038	145,265
Germany	38,091.51	14,571.92	.38	4,169,365,947	109,456
India	32,099.00	-	-	1,424,708,489	44,385
Italy	10,538.00	-	-	1,346,360,000	127,762
Japan	5,129.66	638.87	.12	408,009,023	79,539
Netherlands	2,249.88	912.25	.41	-	-
New Zealand	2,717.00	-	-	138,760,831	51,071
Norway	1,848.10	300.56	.16	77,142,736	41,741
Portugal	1,520.21	-	-	-	-
Roumania	1,978.50	-	-	190,523,900	96,429
Russia (European)	41,817.74	9,162.10	.22	3,538,289,716	84,612
Spain (1909)	9,070.95	-	-	729,929,464	80,483
Sweden	8,587.81	-	-	286,183,902	33,324
Switzerland	2,839.52	633.85	.22	341,208,393	120,164
United Kingdom	23,389.00	16,462.00	.70	6,416,555,277	274,298
United States	240,439.00	25,354.00	.11	18,417,132,238	76,598
Total	530,550.00				

COMPARATIVE RAILWAY STATISTICS
- 1910 -

Sheet No.2

Country	Total Operating Revenue Dollars (6)	Total Operating Revenue Per Mile of Line Dollars (7)	Total Operating Expense Dollars (8)	Total Operating Expense Per Mile of Line Dollars (9)	Net Operating Revenue Dollars (10)	Net Operating Revenue Per Mile of Line Dollars (11)	Net Operating Revenue In Per Cent of Capital (11a)
Argentina	107,058,457	6,158	63,622,090	3,659	43,436,367	2,499	5.00%
Austria-Hungary	295,479,499	12,574	-	-	-	-	-
Belgium	65,893,103	22,472	41,737,247	14,234	24,155,856	8,238	4,41%
Brazil (1908)	33,594,247	2,811	26,635,127	2,229	6,959,120	582	-
Canada	173,956,217	7,033	120,405,440	4,868	53,550,777	2,165	3.11%
Denmark	11,806,713	9,744	11,031,925	9,105	774,788	639	1.23%
Egypt	16,806,526	11,565	9,753,671	6,712	7,052,855	4,853	-
France	352,643,512	14,065	212,068,769	8,458	140,574,743	5,607	3.86%
Germany	726,016,346	19,059	488,462,563	12,823	237,553,783	6,236	5.70%
India	165,956,439	5;170	88,125,114	2,745	77,831,325	2,425	5.46%
Italy	109,666,618	10,406	90,659,748	8,603	19,006,870	1,803	1.41%
Japan	43,035,498	8,389	22,013,209	4,291	21,022,289	4,098	5.15%
Netherlands	25,524,186	11,344	20,846,514	9,265	4,677,672	2,079	-
New Zealand	15,815,103	5,821	10,557,745	3,885	5,257,358	1,966	3.78%
Norway	6,287,858	3,402	4,693,608	2,539	1,594,250	863	2.07%
Portugal	11,437,481	7,523	5,543,018	3,646	5,894,463	3,867	-
Roumania	16,295,149	8,236	10,273,610	5,192	6,021,539	3,044	3.16%
Russia(European)	503,251,265	12,034	338,250,766	8,089	165,141,463	3,949	4.67%
Spain (1909)	65,543,738	7,225	32,194,639	3,549	33,349,099	3,676	4.57%
Sweden	38,072,556	4,433	27,571,051	3,210	10,501,505	1,223	3.67%
Switzerland	42,930,471	15,118	27,130,091	9,554	15,800,380	5,564	4.63%
United Kingdom	603,083,762	25,784	372,626,328	15,931	230,457,434	9,853	3.60%
United States	2,750,667,435	11,440	1,822,630,433	7,580	928,037,002	3,860	5.04%

COMPARATIVE RAILWAY STATISTICS
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Sheet No.3

Country	Passengers Carried Number 12	Passengers Carried Per Mile of Line Number 13	Passengers Carried One Mile Passenger-Miles 14	Passengers Carried One Mile Per Mile of Line Passenger-Miles 15	Average Distance Of Passenger Travel Miles 15a	Average Receipts Per Passenger-Mile Cents 16
Argentina	59,014,600	3,394	1,469,286,000	84,517	24.9	-
Austria-Hungary	394,620,531	16,793	7,406,240,921	315,171	18.8	1.009
Belgium	193,069,662	65,848	2,674,155,288	911,996	13.8	.743
Brazil (1908)	31,163,898	2,608	457,735,268	38,308	14.7	1.565
Canada	35,894,575	1,451	2,466,729,644	99,742	68.8	1.866
Denmark	21,935,030	18,101	490,465,179	404,817	22.4	1.080
Egypt	25,727,045	17,704	-	-	-	-
France	508,558,187	20,285	10,482,294,329	418,087	20.6	1.075
Germany	1,572,531,428	41,283	22,120,226,195	580,712	14.1	.904
India	371,576,000	11,576	13,432,477,000	418,470	36.2	.414
Italy	110,407,600	10,477	-	-	-	-
Japan	153,088,066	29,844	3,000,753,389	584,980	19.6	.701
Netherlands	46,221,000	[illegible],543	-	-	-	.701
New Zealand	11,141,142	4,100	-	-	-	1.425
Norway	13,079,037	7,077	208,282,666	112,700	15.9	-
Portugal	14,888,707	9,793	-	-	-	1.207
Roumania	9,169,849	4,634	-	-	-	-
Russia (European)	208,110,321	4,975	12,991,298,100	310,665	62.4	.700
Spain (1909)	51,408,194	5,667	1,173,498,310	129,368	22.8	-
Sweden	58,276,650	6,785	977,772,635	113,858	16.8	1.238
Switzerland	110,068,465	38,763	1,436,330,743	505,836	13.0	1.290
United Kingdom	1,306,728,583	55,869	-	-	-	-
United States	971,683,197	4,040	32,338,496,329	134,497	33.3	1.938

COMPARATIVE RAILWAY STATISTICS
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Sheet No.4

Country	Tons Carried Short Tons 17	Tons Carried Per Mile of Line Short Tons 18	Tons Carried One Mile Short Ton Miles 19	Tons Carried One Mile Per Mile of Line Short Ton Miles 20	Average Haul of Freight Miles 20a	Average Receipts Per Short Ton-Mile Cents 21
Argentina	36,934,502	2,124	4,493,880,000	258,499	121.6	-
Austria-Hungary	217,083,116	9,237	14,948,353,591	636,124	68.9	1.341
Belgium	83,945,816	28,628	-	-	-	1.073
Brazil (1908)	6,001,380	502	491,230,928	41,111	81.8	5.160
Canada	74,482,866	3,011	15,712,127,701	635,321	210.9	.739
Denmark	5,384,249	4,444	285,398,893	235,561	53.0	1.956
Egypt	4,249,855	2,924	-	-	-	-
France	190,912,114	7,614	15,020,340,438	599,069	74.7	1.203
Germany	596,972,507	15,672	35,484,435,058	931,557	59.4	1.275
India	73,475,360	2,289	13,544,065,920	421,946	184.2	.729
Italy	42,364,890	4,020	-	-	-	-
Japan	28,908,850	5,635	2,175,099,038	424,024	75.2	.740
Netherlands	17,688,202	7,861	-	-	-	1.232
New Zealand	5,850,224	2,153	-	-	-	-
Norway	5,388,052	2,915	200,738,777	108,619	37.1	1.642
Portugal	5,338,984	3,512	-	-	-	-
Roumania	7,676,837	3,880	-	-	-	1.260
Russia (European)	262,494,980	6,277	22,002,600,411	526,151	83.8	.934
Spain (1909)	34,665,365	3,821	2,110,494,872	232,665	60.8	-
Sweden	40,763,674	4,746	1,822,766,634	212,250	44.7	1.404
Switzerland	18,760,355	6,607	854,197,391	300,824	45.5	2.640
United Kingdom	576,160,265	24,634	-	-	-	-
United States	1,026,491,782	4,269	255,016,910,451	1,060,[illegible]	248.5	.753

COMPARATIVE RAILWAY STATISTICS
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Sheet No.5

Country	Locomotives Number 22	Locomotives Per Mile of Line Number 23	Passenger Train Cars Number 24	Passenger Train Cars Per Mile of Line Number 25	Freight and Other Cars Number 26	Freight and Other Cars Per Mile of Line Number 27
Argentina	2,814	.16	4,346	.25	61,549	3.5
Austria-Hungary	11,209	.48	27,424	1.17	233,523	10.0
Belgium	4,458	1.52	10,884	3.72	92,445	31.5
Brazil (1908)	1,144	.10	1,614	.13	14,385	1.2
Canada	4,079	.16	4,320	.17	128,361	5.2
Denmark	604	.50	1,815	1.50	8,681	7.2
Egypt	-	-	-	-	-	-
France	12,840	.51	50,247	2.00	328,934	13.1
Germany	27,662	.73	61,638	1.62	592,988	15.6
India	7,245	.23	20,372	.64	149,628	4.7
Italy	5,376	.51	12,502	1.19	96,159	9.1
Japan	2,305	.45	6,144	1.20	35,239	6.9
Netherlands	1,162	.52	3,014	1.34	20,850	9.3
New Zealand	465	.17	1,140	.42	17,220	6.3
Norway	362	.20	865	.47	7,782	4.2
Portugal	-	-	-			-
Roumania	-	-		-	-	-
Russia (European)	20,289	.48	26,747	.64	455,177	10.9
Spain (1909)	2,533	.28	6,189	.68	50,109	5.5
Sweden	1,921	.22	3,631	.42	47,267	5.5
Switzerland	1,602	.57	4,611	1.63	17,907	6.3
United Kingdom	22,840	.98	72,815	3.11	766,729	32.8
United States	58,947	.24	47,095	.20	2,243,236	9.4

COMPARATIVE RAILWAY STATISTICS
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Sheet No.6

Country	Average Number of Employees Number 28	Average Number of Employees Per Mile of Line Number 29	Compensation of Employees Dollars 30	Average Yearly Compensation of Employees Dollars 31
Argentina	101,255	5.8	46,223,000	456
Austria-Hungary	408,564	17.4	119,149,065	292
Belgium	73,886	25.2	-	-
Brazil (1909)	-	-	-	-
Canada	123,768	5.0	67,167,793	542
Denmark	12,716	10.5	-	-
Egypt	-	-	-	-
France	339,032	13.5	-	-
Germany	706,524	18.5	271,624,174	384
India	543,493	16.9	-	-
Italy	162,000	15.4	49,929,100	308
Japan	94,594	18.4	9,793,947	103
Netherlands	-	-	-	-
New Zealand	12,224	4.5	-	-
Norway	5,949	3.2	-	-
Portugal	-	-	-	-
Roumania	-	-	-	-
Russia (European)	776,730	18.6	164,429,132	393
Spain (1909)	-	-	-	-
Sweden	-	-	-	-
Switzerland	41,179	14.5	13,406,315	326
United Kingdom	-	-	-	-
United States	1,669,470	7.0	1,143,725,306	685

TABLE XXXIII.

LOCOMOTIVE DEVELOPMENT—U. S.

TABLE XXXIII

SHOWING DEVELOPMENT OF LOCOMOTIVES IN THE UNITED STATES ACCORDING TO SIZE

1832 - 1914

Date	Railroad	Type	Builder	Cylinder	Diam. Drivers	Service	Weight-Lbs.
1832	Phila. Germantown & Norristown	2.2.0	Baldwin	9-1/2"x 18"	54"	Mixed	10,000
1836	Beaver Meadow	4.4.0	Eastwick and Harrison	12 x 18	44	Mixed	33,600
1844	Phila.& Reading	0.6.0	Baldwin	15 x 18	46	Freight	40,000
1846	Phila.& Reading	0.8.0	Baldwin	17-1/4 x 18	42	Freight	56,000
1849	Vermont Central	6.2.0	Baldwin	17-1/4 x 20	78	Passenger	50,000
1849	Erie	0.8.0	Baldwin	18-1/4 x 23	48	Pusher	73,700
1856	Pennsylvania	4.6.0	Baldwin	19 x 22	48	Freight	70,000
1857	Baltimore & Ohio	4.4.0	Mason	16 x 22	60	Passenger	70,500
1857	Phila.& Reading	0.12.0	Company's shops	20 x 26	43	Pusher(Tank)	100,000
1863	Baltimore & Ohio	4.6.0	Company's shops	19 x 26	60	Passenger	90,700
1866	Lehigh Valley	2.8.0	Baldwin	20 x 24	48	Freight	90,000
1873	Baltimore & Ohio	2.8.0	Danforth	20 x 24	50	Freight	105,200
1878	Atchison, Topeka & Santa Fe	2.8.0	Baldwin	20 x 26	42	Freight	115,000
1882	Central Pacific	4.8.0	Company's shops	19 x 30	54	Freight	123,000
1888	Central Pacific	4.10.0	Company's shops	21 x 36	57	Freight	154,000
1889	Michigan Central	4.6.0	Schenectady	20-29 x 24	68	Passenger	127,000*
1891	Erie	2.10.0	Baldwin	16-27 x 28	50	Freight	195,000
1899	Illinois Central	4.8.0	Brooks	23 x 30	57	Freight	232,200
1903	Atchison, Topeka & Santa Fe	2.10.2	Baldwin	19-32 x 32	57	Freight	287,240
1904	Baltimore & Ohio	0.6.6.0	Am. Locomotive Co.	20-32 x 32	56	Freight	334,500**
1907	Pennsylvania	4.6.2	Am. Locomotive Co.	24 x 26	80	Passenger	270,000
1909	Atchison, Topeka & Santa Fe	2.8.8.2	Baldwin	26-38 x 34	63	Freight	450,000
1910	Atchison, Topeka & Santa Fe	2.10.10.2	Company's shops	28-38 x 32	62	Freight	500,000
1911	Pennsylvania	4.6.2	Am. Locomotive Co.	27 x 28	80	Passenger	317,000
1913	Virginian	2.8.8.2	Am. Locomotive Co.	28-44 x 32	56	Freight	542,500
1914	Erie	2.8.8.8.2	Baldwin	2 H.P. 36 x 32 4 L.P. 36 x 32	63	Freight	853,050

*First compound locomotive

**First articulated locomotive

TABLE XXXIV

CLASSIFICATION OF FREIGHT CARS, BY CAPACITY

Class in Lbs.	1914 Number	1914 Aggregate Capacity Tons	1914 Average	1913 Number	1913 Aggregate Capacity Tons	1913 Average	1912 Number	1912 Aggregate Capacity Tons	1912 Average	1911 Number	1911 Aggregate Capacity Tons	1911 Average
10,000	608	4,520	7	645	4,812	7	1,156	7,808	7	1,643	10,433	6
20,000	3,548	39,840	11	3,826	43,101	11	4,631	51,364	11	5,170	57,161	11
30,000	3,506	53,014	15	4,200	63,454	15	5,651	85,334	15	4,548	68,863	15
40,000	48,762	975,402	20	58,074	1,161,742	20	73,216	1,464,841	20	87,920	1,759,042	20
50,000	70,526	1,764,386	25	83,454	2,087,646	25	95,182	2,380,951	25	105,666	2,643,293	25
60,000	720,095	21,651,403	30	766,136	23,026,229	30	802,622	24,122,143	30	823,856	24,759,113	30
70,000	42,957	1,504,529	35	43,408	1,525,284	35	39,369	1,378,969	35	39,663	1,389,056	35
80,000	726,777	29,123,756	40	691,078	27,694,420	40	642,734	25,756,980	40	614,788	24,638,503	40
90,000	9,709	437,080	45	7,572	340,915	45	6,770	307,320	45	6,688	303,632	45
100,000	637,741	31,916,914	50	568,823	28,455,491	50	509,624	25,487,794	50	475,871	23,794,047	50
110,000	56,006	3,119,752	56	44,544	2,475,568	55	33,523	1,873,987	56	29,059	1,623,130	56
120,000	716	42,963	60	670	40,203	60	429	25,743	60	158	9,483	60
130,000	320	20,842	65	315	20,518	65	303	19,707	65	-	-	-
140,000	3,435	240,450	70	474	33,180	70	1	70	70	286	20,020	70
150,000	177	13,275	75	58	4,350	75	17	1,275	75	10	750	75
180,000	750	67,500	90	1	90	90	1	90	90	4	360	90
200,000	10	1,000	100	10	1,000	100	9	900	100	-	-	-
280,000	1	142	142	1	142	142	1	142	142	1	142	142
	2,325,644*	90,976,768	39	2,273,289*	86,978,145	38	2,215,239*	82,965,418	37	2,195,331*	81,077,028	37

Class in Lbs.	1910 Number	1910 Aggregate Capacity Tons	1910 Average	1909 Number	1909 Aggregate Capacity Tons	1909 Average	1908 Number	1908 Aggregate Capacity Tons	1908 Average	1907 Number	1907 Aggregate Capacity Tons	1907 Average
10,000	1,894	12,227	6	2,421	14,599	6	3,539	19,713	6	4,277	23,722	6
20,000	5,254	58,196	11	5,785	64,141	11	6,559	74,019	11	7,244	82,990	11
30,000	4,896	74,113	15	5,865	88,925	15	6,697	101,615	15	10,132	152,737	15
40,000	106,741	2,135,652	20	126,500	2,531,476	20	150,499	3,013,519	20	204,583	4,224,943	21
50,000	125,228	3,135,973	25	150,009	3,750,953	25	173,718	4,344,152	25	178,827	4,489,835	25
60,000	826,185	24,831,423	30	830,612	24,960,438	30	832,669	25,017,417	30	802,187	24,112,180	30
70,000	39,310	1,376,486	35	38,926	1,363,528	35	39,838	1,401,197	35	34,652	1,214,028	35
80,000	634,676	25,445,854	40	522,446	20,940,891	40	513,251	20,610,355	40	452,070	18,122,126	40
90,000	6,346	288,818	46	7,891	357,767	45	6,217	283,512	46	5,054	227,485	45
100,000	370,001	18,500,548	50	376,988	18,849,898	50	360,158	18,041,123	50	285,241	14,277,023	50
110,000	12,929	714,875	55	3,824	210,320	55	2,817	155,265	55	1,476	81,510	55
120,000	54	3,243	60	54	3,243	60	54	3,243	60	60	3,603	60
130,000	9	585	65	-	-	-	5	325	65	-	-	-
140,000	-	-	-	-	-	-	-	-	-	-	-	-
150,000	4	300	75	15	1,125	75	11	825	75	12	900	75
180,000	-	-	-	-	-	-	-	-	-	-	-	-
200,000	3	300	100	1	100	100	201	20,100	100	201	20,100	100
280,000	1	142	142	1	142	142	1	142	142	1	142	142
	2,133,531*	75,578,735	36	2,071,338*	73,137,546	35	2,096,234*	73,086,522	35	1,986,017*	67,033,324	34

Class in Lbs.	1906 Number	1906 Aggregate Capacity Tons	1906 Average	1905 Number	1905 Aggregate Capacity Tons	1905 Average	1904 Number	1904 Aggregate Capacity Tons	1904 Average	1903 Number	1903 Aggregate Capacity Tons	1903 Average	1902 Number	1902 Aggregate Capacity Tons	1902 Average
10,000	3,734	20,881	6	4,047	22,487	6	4,812	27,948	6	4,353	24,696	6	5,122	30,393	6
20,000	8,026	93,246	12	9,528	111,601	12	10,241	121,469	12	13,985	162,078	12	15,615	184,253	12
30,000	19,603	295,431	15	27,309	412,492	15	33,507	506,420	15	41,406	624,451	15	46,353	699,484	15
40,000	244,135	5,018,249	21	284,616	5,827,241	20	310,476	6,345,868	20	313,759	6,295,909	20	327,342	6,557,159	20
50,000	195,944	4,907,357	25	206,950	5,179,388	25	223,437	5,591,184	25	235,236	5,884,352	25	246,684	6,169,527	25
60,000	768,647	23,094,297	30	738,704	22,189,879	30	707,985	21,270,011	30	696,393	20,880,912	30	634,626	19,029,245	30
70,000	30,169	1,056,835	35	26,261	920,545	35	27,078	952,040	35	25,285	885,441	35	22,493	787,673	35
80,000	362,336	14,520,159	40	294,462	11,802,898	40	260,784	10,454,010	40	225,541	9,038,204	40	158,179	6,355,215	40
90,000	4,175	187,981	45	2,308	103,863	45	2,240	100,803	45	261	11,838	45	310	14,203	46
100,000	195,911	9,802,763	50	132,729	6,636,456	50	107,287	5,361,858	50	93,917	4,695,790	50	48,834	2,441,700	50
110,000	675	37,125	55	444	24,420	55	430	23,650	55	432	23,760	55	389	21,395	55
120,000	70	4,203	60	56	3,363	60	62	3,722	60	45	2,700	60	43	2,580	60
130,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
140,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
150,000	9	675	75	6	450	75	2	150	75	2	150	75	2	150	75
180,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
200,000	201	20,100	100	200	20,000	100	-	-	-	-	-	-	-	-	-
280,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	833,635*	59,059,302	32	1,727,620*	53,255,083	31	1,688,841*	50,759,133	30	1,650,615*	48,530,281	29	1,505,992*	42,292,977	28

1914: *Excludes 3 cars of 220,000-lb. class, aggregating 330 tons capacity.

Does not include returns for the so-called small roads (having operating revenue below $100,000) and returns for switching and terminal companies.

1913: *Excludes 275 cars in freight service for which complete returns were not secured.

Does not include returns for the so-called small roads, (having operating revenue below $100,000) and returns for switching and terminal companies.

1912: *Does not include cars in the service of switching and terminal companies.

Excludes 310 cars in freight service for which complete returns were not secured.

1911: *Does not include cars in the service of switching and terminal companies.

Excludes 180 cars in freight service for which complete returns were not secured.

1910: *Does not include cars in the service of switching and terminal companies.

Excludes 1,590 cars in the freight service for which complete returns were not secured.

1909: *Does not include cars in the service of switching and terminal companies.

Excludes 2,268 cars in the freight service for which complete returns were not secured.

1908: *Includes 11,067 cars in the service of switching and terminal companies.

Excludes 4,550 cars in the freight service for which complete returns were not secured.

1907: *Excludes 5,540 cars in the freight service for which complete returns were not secured.

1906: *Excludes 4,279 cars in the freight service for which complete returns were not secured.

1905: *Excludes 3,789 cars in the freight service for which complete returns were not secured.

1904: *Excludes 3,853 cars in the freight service for which complete returns were not secured.

1903: *Excludes 3,167 cars in the freight service for which complete returns were not secured.

1902: *Excludes 40,109 cars in the freight service for which complete returns were not secured.

TABLE XXXV

VARIOUS GAUGES IN USE IN CERTAIN SELECTED COUNTRIES

EUROPE

Country	Year		Length of Line Miles
Austria-Hungary	1910	4'-8-1/2" (1.435m)	18,882.48
		5'-0-5/16"(1.532m) & 4'-8-1/2"(1.435m)	137.33
		4'-8-1/2" (1.435m) & 2'-6" (.76m)	1,460.91
		1.0m (3'-3-3/8")	106.87
		2'-6" (.76m)	384.65
		.75m (2'-5-17/32")	8.70
		.70m (2'-3-9/16")	10.56
		Length given here 3,609.7 km. less than tabulated for 1910.	
Belgium	1908	4'-8-1/2" (1.435m)	*2,695.63
		3'-6" (1.067m)	°304.49
		1.0 m (3'-3-3/8")	°2,269.35
		*309.4 km. less than tabulated for 1900 °Presumably tramways.	
France	1910	4'-8-1/2" (1.435m)	23,805.83
		1.0 m (3'-3-3/8")	1,322.34
		General railways only.	
Germany	1910	4'-8-1/2" (1.435m)	36,827.27
		1.0 m (3'-3-3/8")	821.49
		1.0 m (3'-3-3/8") & 4'-8-1/2"(1.435m)	1.24
		.785m (2'-6-29/32")	157.21
		.75m (2'-5-17/32")	370.36
Italy	1900	4'-8-1/2" (1.435m)	*9,117.80
		.954m (3'-1-9/16") & .85m (2'9-15/32")	752.52
		*Corrected to check with tabulation.	
Norway	1910	4'-8-1/2" (1.435m)	*976.94
		4'-8-1/2" (1.435m) & 3'-6" (1.067m)	101.91
		3'-6" (1.067m)	692.86
		1.0 m (3'-3-3/8")	14.29
		.75m (2'-5-17/32")	62.76
		*Corrected to check with tabulation	
Sweden	1910	4'-8-1/2" (1.435m)	5,556.39
		3'-7" (1.093m)	30.45
		3'-6" (1.067m)	314.43
		2'-11" (.891m)	1,546.66
		2'-7-1/2" (.802m)	49.71
		.60m (1'-11-5/8")	95.70
Switzerland	1910	4'-8-1/2" (1.435m)	*2,123.95
		1.0 m (3'-3-3/8")	672.98
		.80m (2'-7-31/32")	36.04
		.75m (2'-5-17/32")	34.80
		*Corrected to check with tabulation.	
United Kingdom	1910	5'-3"	2,867.00
		4'-8-1/2"	*19,829.00
		4'-6"	11.00
		4'-0"	21.00
		3'-0"	541.00
		2'-6"	21.00
		2'-4-1/2"	9.00
		2'-4"	3.00
		2'-3"	24.00
		1'-11-1/2"	63.00
		*Corrected to check with tabulation.	
		OTHER COUNTRIES	
Argentine Republic	1912	5'-6"	12,360.00
		4'-8-1/2"	1,645.00
		1.0 m (3'-3-3/8")	6,397.00
Australia	1913	5'-3"	4,344.00
		4'-8-1/2"	4,107.00
		3'-6"	10,883.00
		2'-6"	122.00
		2'-0"	231.00
Canada	1910	4'-8-1/2"	24,462.00
		3'-6"	269.00
India	1910	5'-6"	16,701.00
		1.0 m (3'-3-3/8")	13,530.00
		2'-6"	1,436.00
		2'-0"	432.00
Japan	1910	3'-6"	5,062.66
		2'-6"	67.00
New Zealand	1910	3'-6"	2,717.00

TABLE XXXVIII

PERSONS KILLED AND INJURED IN SIXTEEN COUNTRIES

								Passengers						Employees				Others			
								Killed			Injured			Killed		Injured		Killed		Injured	
Country	Year	Length Of Line 1000 Miles	Passengers Carried 10 Millions	Passenger Miles 100 Millions	Number of Employees Thousands	TOTAL Killed	TOTAL Injured	Total	Per 10 Million Carried	Per 100 Million Passenger Miles	Total	Per 10 Million Carried	Per 100 Million Passenger Miles	Total	Per 1000 Employed	Total	Per 1000 Employed	Total	Per 1000 Miles Of Line	Total	Per 1000 Miles Of Line
Austria-Hungary	1880	11.4	4.05	12.2	127.9	152	421	3	.74	.25	32	7.83	2.62	83	.65	320	2.50	66	5.8	69	6.0
	1890	16.4	9.78	23.0	177.1	243	993	14	1.43	.51	183	18.72	7.96	138	.78	711	4.02	91	5.5	99	6.0
	1900	19.6	22.25	46.6	295.4	409	1,396	24	1.08	.52	198	8.89	4.25	192	.65	939	3.18	193	9.8	259	13.2
	1910	23.5	39.46	74.1	408.6	647	3,036	53	1.34	.71	524	13.28	7.06	252	.62	2,067	5.06	342	14.5	445	18.9
Belgium	1880	1.7	4.3	-	-	145	453	6	1.40	-	74	17.20	-	105	-	339	-	34	20.0	40	23.5
	1890	2.9	8.24	8.5	52.0	126	892	7	.85	.82	80	9.71	9.41	72	1.38	845	16.25	47	16.2	67	23.1
	1900	2.9	13.91	16.7	67.7	105	1,738	10	.71	.59	491	35.10	29.40	53	.78	1,185	17.50	42	14.5	62	21.4
	1910	2.9	19.30	26.7	73.9	136	975	11	.56	.41	359	18.60	13.45	77	1.04	535	7.24	48	16.5	81	27.9
Canada	1880	6.9	.75	-	-	87	101	10	13.34	-	4	5.33	-	27	-	76	-	50	7.8	21	3.0
	1890	13.3	1.28	-	-	218	835	11	8.59	-	52	40.60	-	83	-	682	-	124	9.3	101	7.6
	1900	17.7	2.15	-	-	325	1,317	7	3.25	-	131	61.00	-	123	-	941	-	195	11.0	245	13.8
	1910	24.7	3.59	24.7	123.8	524	1,441	60	16.70	2.43	270	75.20	10.94	214	1.73	926	7.48	250	10.1	245	10.0
Denmark	1880	.5	.26	.5	2.3	6	6	1	3.84	2.00	1	3.84	2.00	4	1.74	5	2.17	1	2.0	0	-
	1890	1.0	.90	1.6	6.3	8	37	0	0	0	1	1.11	.62	2	.32	32	5.08	6	6.0	4	4.0
	1900	1.1	1.73	3.4	10.0	22	109	0	0	0	12	6.83	3.53	11	1.10	94	9.40	11	10.0	3	2.7
	1910	1.2	2.19	4.9	12.7	30	24	2	.91	.41	2	.91	.41	9	.71	17	1.34	19	15.8	5	4.2
France	1880	14.7	16.51	36.3	204.7	426	1,390	35	2.12	.96	377	22.85	10.38	269	1.31	936	4.57	122	8.3	77	5.2
	1890	20.8	24.11	49.3	233.0	403	1,020	45	1.86	.92	224	9.28	4.54	194	.83	683	2.93	164	7.8	113	5.4
	1900	23.6	44.32	87.3	286.8	678	1,577	94	2.12	1.07	375	8.46	4.28	314	1.09	1,007	3.51	270	11.4	195	8.3
	1910	25.1	50.86	104.8	339.0	753	1,522	110	2.16	1.05	600	11.80	5.72	320	.94	631	1.86	323	12.8	291	11.6
Germany	1880	21.0	21.52	40.0	284.9	455	2,214	26	1.21	.65	138	6.41	3.45	250	.87	1,897	6.67	179	8.5	179	8.5
	1890	26.6	43.41	70.0	401.4	730	2,485	46	1.06	.65	244	5.62	3.48	463	1.15	2,060	5.13	221	8.3	181	6.8
	1900	32.1	87.92	125.7	541.0	994	2,447	121	1.38	.96	600	6.82	4.77	564	1.04	1,560	2.88	309	9.5	287	8.6
	1910	38.1	157.25	221.2	706.5	978	2,385	100	.64	.45	676	4.30	3.06	550	.78	1,448	2.15	288	7.6	261	6.8
India	1880	7.2	3.41	9.2	132.0	364	359	31	9.36	3.37	38	11.14	4.13	135	1.02	240	1.82	198	27.5	81	11.2
	1890	16.1	11.06	46.8	238.2	534	1,024	72	6.51	1.54	300	27.12	6.40	165	.69	615	2.58	297	18.4	109	6.8
	1900	24.7	17.48	70.1	350.2	1,101	1,106	97	5.55	1.38	333	19.05	4.75	257	.73	477	1.36	747	30.5	296	12.0
	1910	32.1	37.16	134.3	543.5	1,700	1,664	187	5.03	1.39	659	17.74	4.90	398	.73	653	1.20	1,115	34.7	352	11.0
Italy	1880	5.3	3.25	-	-	179	688	9	2.77	-	52	16.00		66	-	562	-	104	19.6	74	13.9
	1890	8.0	5.08	-	-	142	651	7	1.38	-	141	27.75		65	-	402	-	70	8.7	108	13.5
	1900	9.9	5.97	-	-	144	1,142	33	5.53	-	326	54.60		63	-	729	-	48	4.9	87	8.8
	1910	10.6	11.04	-	162.0	272	2,610	42	3.80	-	780	70.60		62	.38	1,550	9.57	168	15.9	380	26.6
Japan	1880	.1	-	-	-											-				-	
	1890	1.1	-	-	-											-				-	
	1900	3.6	10.21	17.1	53.8	536	1,062	33	3.23	1.93	329	32.20	19.23	98	1.82	478	8.88	405	112.5	255	70.8
	1910	5.1	15.31	30.0	94.6	517	2,002	21	1.37	.70	345	22.50	11.50	140	1.48	1,205	12.23	356	69.8	452	88.6
Netherlands	1880	1.4	1.60	-	-	29	38	3	1.87	-	1	.62	-	18	-	34	-	8	5.7	3	2.1
	1890	1.7	1.70	-	-	41	38	6	3.53	-	10	5.88	-	14	-	23	-	21	12.3	5	2.9
	1900	2.0	3.00	-	-	55	81	4	1.33	-	15	5.00	-	27	-	51	-	24	12.0	15	7.5
	1910	2.2	4.62	-	-	53	119	3	.65	-	44	9.52	-	26	-	58	-	24	11.0	17	7.7
Russia	1880	14.1	3.37	-	-	455	979	23	6.82	-	68	20.18	-	256	-	778	-	176	12.5	133	9.4
	1890	18.1	4.65	31.1	252.4	646	1,443	28	6.02	.90	103	22.15	3.31	209	.83	486	1.92	409	22.6	854	47.2
	1900	32.6	10.70	72.7	554.3	2,086	8,204	97	9.06	1.33	609	56.92	8.37	489	.88	1,918	3.46	1,500	46.0	5,677	174.1
	1910	41.8	20.81	129.9	776.7	3,635	14,521	227	10.90	1.75	1,161	55.80	8.94	603	.78	3,395	4.37	2,805	67.1	9,965	238.5
Spain	1880	4.6	1.48	-	-	82	621	2	1.35	-	36	24.31	-	37	-	520	-	43	9.3	65	14.1
	1890	6.2	2.58	-	-	131	367	9	3.49	-	72	27.91	-	31	-	215	-	91	14.7	80	12.9
	1900	8.2	3.20	-	-	169	485	13	4.06	-	67	20:93	-	32	-	312	-	124	15.1	106	12.9
	1910	9.1	5.14	11.7	-	318	2,622	11	2.14	.94	49	9.53	4.19	65	-	2,294	-	242	26.6	279	30.6
Sweden	1880	3.7	.70	-	-	13	10	0	-	-	-	-	-	7	-	7	-	6	1.6	3	.8
	1890	5.0	1.27	2.4	-	35	71	1	.78	.42	3	2.36	1.25	15	-	63	-	19	3.8	5	1.0
	1900	7.0	3.08	5.1	-	101	267	6	1.95	1.17	11	3.57	2.15	37	-	225	-	58	8.3	31	4.4
	1910	8.6	5.83	9.8	-	86	201	8	1.37	.82	14	2.40	1.43	25	-	166	-	53	6.2	21	2.4
Switzerland	1880	1.6	2.16	2.8	13.2	41	78	7	3.24	2.50	16	7.41	5.71	16	1.21	45	3.41	18	11.2	17	10.1
	1890	1.9	3.24	4.4	19.7	49	383	7	2.16	1.59	22	6.79	5.00	20	1.01	330	16.75	22	11.6	31	16.3
	1900	2.3	6.28	7.7	28.7	55	791	7	1.11	.91	62	9.88	8.05	23	.80	[illegible]	24.35	25	10.9	30	13.0
	1910	3.8	11.00	14.4	41.2	71	1,475	7	.64	.48	90	8.18	6.25	32	.78	1,341	32.54	32	8.4	44	11.6
United Kingdom	1880	17.9	60.38	-	-	1,181	6,691	147	2.35	-	1,817	30.20	-	567	-	4,480	-	477	26.6	394	22.0
	1890	20.0	81.77	-	-	1,135	11,568	121	1.48	-	1,720	21.05	-	508	-	9,380	-	505	25.2	468	23.4
	1900	21.8	114.23	-	-	1,310	19,547	142	1.24	-	3,068	21.60	-	616	-	15,655	-	552	25.3	824	37.8
	1910	23.4	130.67	-	-	1,121	30,110	121	.93	-	4,080	31.15	-	420	-	25,137	-	580	24.8	893	38.3
United States	1880	87.8	26.96	57.4	418.9	2,541	5,674	143	5.30	2.49	544	20.14	9.47	923	2.20	3,617	8.64	1,475	16.8	1,513	17.2
	1890	163.6	49.24	118.5	749.3	6,335	29,027	286	5.80	2.41	2,425	49.30	20.48	2,451	3.27	22,396	29.91	3,598	21.9	4,206	25.6
	1900	193.3	57.68	160.4	1,017.6	7,865	50,320	249	4.31	1.55	4,128	71.60	25.75	2,550	2.50	39,643	38.88	5,066	26.2	6,649	33.9
	1910	240.4	97.17	323.4	1,669.4	9,682	119,507	324	3.33	1.00	12,451	128.20	38.50	3,382	2.03	95,671	57.30	5,976	24.9	11,385	47.4
United States 1911-1914 Inclusive	1911					10,396	150,159	356			13,433			3,602		126,039		6,438		10,687	
	1912					10,585	169,538	318			16,386			3,635		142,442		6,632		10,710	
	1913					10,964	200,308	403			16,539			3,715		171,417		6,846		12,352	
	1914					10,302	192,662	265			15,121			3,259		165,212		6,728		12,329	

TABLE XLV.

Relative Standing of Various Countries in 1910 in Respect to Others Than Passengers or Employees Killed per 1,000 Miles of Line.

	Country	Killed
1.	Sweden	6.2
2.	Germany	7.6
3.	Switzerland	8.4
4.	Canada	10.1
5.	Netherlands	11.0
6.	France	12.8
7.	Austria-Hungary	14.5
8.	Denmark	15.8
9.	Italy	15.9
10.	Belgium	16.5
11.	United Kingdom	24.8
12.	United States	24.9
13.	Spain	26.6
14.	India	34.7
15.	Russia	67.1
16.	Japan	69.8

TABLE XLVI.

Relative Standing of Various Countries in 1910 in Respect to Others Than Passengers or Employees Injured per 1,000 Miles of Line.

	Country	Injured
1.	Sweden	2.4
2.	Denmark	4.2
3.	Germany	6.8
4.	Netherlands	7.7
5.	Canada	10.0
6.	India	11.0
7.	France	11.6
8.	Switzerland	11.6
9.	Austria-Hungary	18.9
10.	Italy	26.6
11.	Belgium	27.9
12.	Spain	30.6
13.	United Kingdom	38.3
14.	United States	47.4
15.	Japan	88.6
16.	Russia	238.5

In the matter of ownership, while there is still great diversity in practice, there is undoubtedly a steady tendency towards government ownership, or at least more rigorous government control. When railways were first projected in England and the United States they were regarded much as turnpike enterprises—purely private concerns with no thought of participation by the government, either national or local, either as part owners, contributors or controlling agents. This policy, except as to some form of government control, has been adhered to in the United Kingdom and in no other country.

The railways in the United Kingdom still are strictly private enterprises, organized under special powers conferred by Acts of Parliament, but without public aid or subsidy. General Acts of Parliament have been passed from time to time since the "Cheap Trains Act" of 1844, regulating more and more closely the operation of the railways in regard to rates, powers to amalgamate, prevention of discrimination, pooling of earnings, and subjecting them to inspection by the Board of Trade. The facts are, however, that railway companies have greater liberty of action in the United Kingdom than in any other country, their chief powers being established once and for all in the incorporating act, and that the United Kingdom stands as the only country that has encouraged its railway system to be developed and maintained without government assistance.

In the United States participation by the public authorities has followed different lines. When railways were first projected the country was very sparsely settled, distances were great and traffic was small, and two things became speedily obvious: First, that private capital needed some assistance, and, second, that the benefit to the land owners and towns along the lines was as great or greater than to the promoters of railway enterprises, and that, therefore, some portion of the cost and corresponding risk should be assumed by those who, without other effort, received enormous benefits. There therefore sprang up a system by which not only the local municipalities but in many cases the States themselves contributed in one form or another to the construction of railways, culminating in what afterwards turned out to be the very extensive assistance given by the Federal Government itself in the way of grants of land to the railways in the West; land that

without railway communication was practically worthless, but which with it has since developed into great value.

During the rapid increase in railway construction following the Civil War this participation of various municipalities in pledging their credit to the support of railway enterprises which, unfortunately, in some instances were chimerical schemes, one state after another was led to pass acts prohibiting either the state or any portion thereof from pledging its credit to assist railway construction.

With but few exceptions, and those exceptions are so trifling as to be negligible, there is no form of government ownership of railways in the United States, the companies all remaining as private enterprises. On the Isthmus of Panama the United States Government now owns the Panama Railroad, through stock ownership, and in the Territory of Alaska the United States Government has recently embarked, for the first time, in the construction of a government railway.

As the railways have increased in size and power in the United States, affecting more than any other industry the general activities of the people, it was realized that some form of control was necessary. Rhode Island had a so-called railroad commission as early as 1844, although probably the first real commission was established in New Hampshire in that same year. Connecticut followed in 1853, New York and Vermont in 1855, Maine in 1858, and Massachusetts in 1869, which last developed into a model for state control, to be copied by other states.

In the period of 1870 to 1880 the so-called "Granger Agitation" in the Middle West led to a popular demand for extending not only the principle of state control, but to further increasing its powers wherever it had already been established, a demand that led, in 1887, to a passage by Congress of the Interstate Commerce Commission Act. By various amendments the powers of the Interstate Commerce Commission and the powers of the various state commissions, which latter are now found in all states of the Union, except Delaware and Utah have been greatly broadened and greatly strengthened.

In general, the Interstate Commerce Commission has jurisdiction over the interstate operations of steam and electric railways, express and sleeping car companies, water lines operated

as a part of or in connection with railway transportation, telegraph, telephone, cable and wireless companies. The Commission has power to decide the justice and reasonableness of rates, whether brought to its attention or investigated on its own motion. Proposed changes in schedules may be suspended by the Commission pending investigation. The Commission is empowered to institute a uniform system of accounting for common carriers and to secure such other information as may be necessary to the carrying out of the provisions of the act. The Commission may assess damages in cases of reparation, and in the case of refusal of a carrier to comply with its orders may take action against such carrier in the Federal courts.

The various state commissions have powers regulating the railways within the limits of their own states, and have at times assumed powers that have brought them in conflict with those of the Interstate Commerce Commission. The powers of the state commissions vary greatly in the several states, extending from determining in the first instance whether any given railway should be constructed or not, with control over the issuance of securities and determination of intra-state rates, and to the minor details of actual operation, such as inspection of equipment and the regulation of the number of men to be employed in various capacities.

The titles and powers of state commissions with jurisdiction over railways are as follows:

Year established

1844 Rhode Island
Present title: Public Utilities Commission. Jurisdiction over all public utilities; has power to regulate rates and service, etc.

1844 New Hampshire
Present title: Public Service Commission. Jurisdiction over all railroads, etc., with power to fix rates or to reconstruct roads, etc.

1853 Connecticut
Present title: Public Utilities Commission. Jurisdiction over all common carriers, etc., with power to regulate rates and service.

1855 New York
Present title: Public Service Commission. Two bodies, one

Year established	
	for first district and one for second district. Both bodies have extensive jurisdiction over all common carriers.
1855	Vermont Present title: Public Service Commission. General supervision over all railroads.
1858	Maine Present title: Public Utilities Commission. Authority to inquire into the management of the business of all public utilities; to regulate rates and charges; to prevent the giving of rebates; to investigate accidents; find the physical valuation of properties; to authorize and approve of issue of stocks, bonds, notes or other evidences of indebtedness; to authorize the sale, lease, assignment, mortgage, or consolidation of utilities; may order physical connection and joint use of facilities and equipment of utilities; may fix rates; and may order use by one utility of the equipment of another.
1867	Ohio Present title: Public Service Commission. Commission has power and jurisdiction to supervise and regulate public utilities and railroads, etc.; may supervise and fix rates; and control of the issuance of securities.
1869	Massachusetts Present title: Public Utilities Commission. Jurisdiction over all common carriers.
1871	Illinois Present title: Public Utilities Commission. (Railroad and Warehouse Commission of Illinois abolished.) Jurisdiction over rates, service and schedules, and to supervise the issue of all stocks, bonds, and securities.
1871	Minnesota Present title: Railroad and Warehouse Commission. Jurisdiction over railroads and express companies doing business as common carriers and public warehouses. Commission has power to fix rates.
1873	Michigan Present title: Railroad Commission. Jurisdiction over all common carriers, with power to fix rates and to regulate stock and bond issues.
1874	Wisconsin Present title: Railroad Commission. Jurisdiction to supervise and regulate every public utility in the state; power to require that all public utility charges be reasonable and just, and to this end to fix and determine rates and regulations.

Year established

1875 Missouri

Present title: Public Service Commission. Jurisdiction extends to all "public utility corporations and persons" which operate railroads or other forms of common carriers, etc. Commission has power to regulate rates and service.

1876 California

Present title: Public Utilities Commission under name of "Railroad Commission". Commission is given power to regulate and control all the public utilities of the state.

1877 Virginia

Present title: State Corporation Commission. Control over all public service corporations, including fixing of rates and charges, etc.

1878 South Carolina

Present title: Railroad Commission. General supervision of all railroads and railways, express companies and other common carriers; shall examine and keep themselves informed as to their condition and the manner in which they are operated, with reference to the security and accommodation of the public and the compliance with the laws of the state; and shall make freight and passenger tariffs.

1878 Iowa

Present title: Board of Railroad Commissioners. Board has general supervision of all railroads in the state operated by steam, express companies, car companies, sleeping car companies, freight and freight line companies, and any common carrier engaged in the transportation of passenger or freight by railroads. Has power to supervise rates and fares generally and has been specifically given power to fix rates for express companies.

1879 Georgia

Present title: Railroad Commission. Jurisdiction over all common carriers, express companies, dock and wharfage companies, terminal companies, etc.; may require common carriers and public service corporations to establish and maintain such public service and facilities as may be reasonable and just, and such publication by common carriers, in newspapers of towns through which their lines extend, of their schedules as may be reasonable and which the public demands.

1880 Kentucky

Present title: Railroad Commission. Has power to fix freight or passenger rates; and has jurisdiction over common carriers generally.

Year established

1881 Alabama

Present title: Railroad Commission. Jurisdiction over railroads, express companies, car companies, sleeping car companies, freight and freight lines, steamboat or steam packet companies and terminal companies.

1883 Kansas

Present title: Public Utilities Commission. Jurisdiction over all common carriers.

1883 Tennessee

Present title: Railroad Commission. General supervision and control over all railway companies in the state; empowered to supervise and fix the rates, charges and regulations of railroad freight and passenger tariffs; to correct abuses; to prevent unjust discriminations and extortions in the rates of freight and passenger tariffs in different railroads in the state.

1884 Mississippi

Present title: Railroad Commission. Jurisdiction over railroads, express companies, etc. Commission has power to fix rates, ''make reasonable orders for supervision and regulation''.

1885 North Dakota

Present title: Commissioners of Railroads. Commissioners have general power over common carriers, may fix rates, etc.

1885 Colorado

Present title: Railroad Commission. Jurisdiction over all common carriers, including express companies, private freight car lines and pipe lines, etc.

1885 Nebraska

Present title: State Railway Commission. General control over railroads, express companies, car companies, sleeping car companies, freight and freight line companies, etc., and has power to ''regulate the rates and services and make physical valuation; control over the issue of stocks, bonds, etc''.

1885 South Dakota

Present title: Railroad Commission. Jurisdiction over all common carriers, including warehouses and grain elevators, and has power to fix rates.

1887 Florida

Present title: Railroad Commission. Jurisdiction over rates and service of all railroads, all bridges and ferries, used or operated in connection with any railroad operated wholly or in part in the state; all passenger terminal companies or union depot companies, etc.

Year established	
1887	Oregon Present title: Railroad Commission. Commission has power and jurisdiction to supervise and regulate all public utilities; to prescribe reasonable rates and regulations, etc.
1891	Arizona Present title: Corporation Commission. Jurisdiction over all corporations other than municipal, engaged in carrying persons or property for hire, etc. The Commission may prescribe rates.
1891	North Carolina Present title: Corporation Commission. Commission has general control over railroads and other common carriers, etc.; has power to make rates; to prevent discriminations; to prevent rebates.
1891	Texas Present title: Railroad Commission. Jurisdiction over all steam railroad and express companies, and has power to fix rates.
1898	Louisiana Present title: Railroad Commission. Jurisdiction over railroads, express companies, steamboat and other water craft, sleeping car companies and corporations, etc. Commission has power to regulate rates.
1899	Arkansas Present title: Railroad Commission. Jurisdiction over persons or corporations engaged in the transportation of passengers or property. Commission may fix rates.
1905	Indiana Present title: Public Utilities Commission. Commission has the right to regulate rates, supervise the bond issue of corporations and the sale and transfer of property; also the merger and consolidation of corporations.
1905	Washington Present title: Public Service Commission. Jurisdiction over railroad and express companies, and other common carriers.
1907	Montana Present title: Public Service Commission. Has full power of supervision, regulation and control of public utilities.
1907	Nevada Present title: Public Service Commission. Jurisdiction over all common carriers and may fix standards for service, regulate rates, etc.
1907	Pennsylvania Present title: Public Service Commission. Jurisdiction generally over all railroads and common carriers.

Year established

1908 Oklahoma
Present title: Corporation Commission. Jurisdiction over railroads and other common carriers.

1910 Maryland
Present title: Public Service Commission. Jurisdiction over all railroads of every kind.

1910 New Mexico
Present title: Corporation Commission. Commission has general powers over all railroads.

1911 New Jersey
Present title: Board of Public Utilities Commissioners. General supervision and regulation of all public utilities, with power to fix rates; require schedules of rates to be filed; fix just and reasonable standards, classifications, regulations, practices, etc.

1913 District of Columbia
The Public Utilities Commissioners are the commissioners of the District of Columbia. Jurisdiction over every public utility.

1913 Idaho
Present title: Public Utilities Commission. Jurisdiction over all common carriers, etc., with power to regulate and fix rates and service.

1913 West Virginia
Present title: Public Service Commission. Jurisdiction over all common carriers, with power to supervise rates and service, etc.

Although the railways of the United States are privately owned, they are, nevertheless, large contributors, by means of taxation, to the general government and the individual states, and the tendency has been almost uniform in increasing this burden.

Table XLVII shows the extent to which the railways of the United States have been, since the year 1898, contributors to the support of the government in which there is shown the amount paid each year in taxation, the amount paid to the proprietors of the company in way of dividends, and the ratio the amount received by the general public bears to that received by the owners of the property, that is, the stockholders, although on the latter have fallen all the risks and responsibilities involved in the operation. The amount charged to taxes is exclusive of per-

sonal taxes paid by the holders on bonds or other obligations of railways and exclusive of the sur-tax of the income tax. Since 1898 the smallest ratio of taxes to dividends was in the year 1904, when a sum equal to one-third of the amount paid out in dividends was paid out in taxes. This ratio has increased year by year until the year 1914, when in spite of an increase in dividends the amount paid in taxes now exceeds one-half of that paid out to the stockholders.

TABLE XLVII.

Comparison of Taxes and Dividends Paid on United States Railroads.

Year	Taxes	Dividends	Per Cent
1898	43,828,224	83,995,384	52.18
1899	46,337,632	94,273,796	49.15
1900	48,332,273	118,624,409	40.74
1901	50,944,372	131,626,672	38.70
1902	54,465,437	157,215,380	34.64
1903	57,849,569	166,176,586	34.81
1904	61,696,354	183,754,236	33.58
1905	63,474,679	188,175,151	33.73
1906	74,785,615	213,555,081	35.02
1907	80,312,375	227,394,962	35.32
1908	84,555,146	227,597,070	37.15
1909	90,529,014	236,620,890	38.26
1910	103,795,701	293,836,863	35.32
1911	108,309,512	291,497,164	37.16
1912	120,091,534	299,361,208	40.12
1913	127,331,960	260,864,853	48.81
1914	139,591,520	265,748,161	52.53

On the continent of Europe the relations between the States and the railways are very much more intimate than in the United Kingdom and the United States. From the first, continental European countries, to which the question of national defense is always paramount, perceived that railways would be a great factor in military problems, and that lines should be constructed to meet not only commercial but strategic demands. In France, where continental railways had their inception, the Government at an early date assumed direction of affairs, and has assisted construction by loaning money, guaranteeing interest, and in some instances by actual purchase. Although today the Government owns but about one-fifth of the total mileage, it

nevertheless maintains a very strict regulation of the privately operated lines, nearly all of which are in some manner indebted to the State, and which under existing agreements and concessions will become the property of the State between 1950 and 1960 without additional payment, unless purchased at earlier dates.

In Germany, Prussia has had the right of acquisition since 1838, a right that was actively exercised after the Franco-German war, and today owns and operates all the main lines. This same policy is followed in the other states of the German Empire. The few lines in Germany that are privately operated are controlled absolutely as to tariffs and details of operation by the Government.

Other countries, Russia, Switzerland and Belgium have adopted government ownership and operation, except that in Belgium local railways, known as "Chemins de fer Vicinaux", are operated by private companies under special concessions but for the most part are owned by local municipalities. In Austria-Hungary, Balkan States, Denmark, Italy, Portugal, Norway and Sweden, both government and private ownership and operation exist side by side, but the private corporations are under official regulation. In the Netherlands the lines are owned partly by the government and partly by private companies, but are all under private operation, with traffic rates subject to approval by the minister of railways. In Greece and Spain all railways are under private ownership and operation, but in the latter country have received Government subventions, in return for which they automatically will become government property after a term of years. In Turkey all lines are the property of the State but are operated by private companies.

Outside of the United States, Russia and Germany, the country with the greatest railway mileage is India, where since 1870 the principle of government ownership has prevailed. In 1910 more than 90% of the lines were Indian government or native state owned, of which one-third was operated directly by the governments. Nearly all of the balance has received government aid.

In Asia (other than India), Africa, Central and South America, and in Australasia, government and private ownership

TABLE XLVIII

Showing Division of Ownership
Between Government and Private Corporations

Country	YEAR 1880 Miles of Line: Government Owned	Private Owned	Total	Per Cent of Total Miles Owned by the Government	YEAR 1890 Miles of Line: Government Owned	Private Owned	Total	Per Cent of Total Miles Owned by the Government
Argentina	-	-	1,560	-		-	5,848	-
Australasia	-	-	3,188		-	-	9,798	-
Austria-Hungary	-		11,436	-	-	-	16,437	-
Belgium	-	-	1,692	-	2,018	918	2,936	68.7
Bulgaria	-		-	-	-	-	-	-
Brazil	-		1,988	-	-		5,903	-
Canada	1,038	5 753	6 891	15.1	1,182	12,074	13 256	8.9
*China	7	0	7	100.0	124	0	124	100.0
Denmark	531	89	620	85.7	950	103	1,053	90.2
Egypt	932	0	932	100.0	961	0	961	100.0
France	-	-	14,736	-	1,571	19,263	20,834	7.5
Germany	16,281	4,771	21,052	77.3	23,934	2,726	26,660	89.8
Greece	0	7	7	0	0	477	477	0
India	9,306	0	9,306	100.0	16,095	0	16,095	100.0
Italy	2,376	2,962	5,340	44.5	5,229	2,754	7,983	65.5
Japan	-	-	73	-	550	586	1,136	48.4
Netherlands	695	748	1,443	48.2	718	935	1,653	43.4
New Zealand	1,288	-	1,288	100.0	1,809	0	1,809	100.0
Norway	614	42	656	93.6	928	42	970	95.7
Portugal	369	341	710	52.0	514	686	1,200	42.8
Roumania	-	-	862	-	-	-	1,580	-
Russia	-	-	14,824	-	5,324	12,840	18,164	29.3
Servie	-	-	-	-	-	-	336	-
Spain	0	4,552	4,552	0	0	6,211	6,211	0
South Africa Union	-	-	-	-	-	-	-	-
Sweden	1,214	2,439	3,653	33.2	1,623	3,356	4,979	32.6
Switzerland	1,443	0	1,443	100.0	1,653	0	1,653	100.0
*Turkey (Europe)	866	0	866	100.0	1,097	0	1,097	100.0
United Kingdom	0	17,933	17,933	0	0	20,073	20,073	0
United States	0	87,832	87,832	0	0	163,597	163,597	0
Total				22.4				21.2

Country	YEAR 1900 Miles of Line: Government Owned	Private Owned	Total	Per Cent of Total Miles Owned by the Government	YEAR 1910 Miles of Line: Government Owned	Private Owned	Total	Per Cent of Total Miles Owned by the Government
Argentina	-	-	10,269	-	2,467	14,881	17,348	14.2
Australasia	-	-	12,642	-	15,312	1,213	16,525	92.7
Austria-Hungary	14,516	5,111	19,627	74.0	19,979	3,520	23,499	85.0
Belgium	2,521	365	2,886	87.4	2,689	243	2,932	91.6
Bulgaria	-	-	-	-	1,106	0	1,106	100.0
Brazil	-	-	9,195	-	5,440	7,839	13,279	41.0
Canada	1,511	16,146	17,657	8.6	2,044	22,687	24,731	8.3
*China	401	0	401	100.0	5,421	0	5,421	100.0
Denmark	1,118	556	1,674	66.8	1,212	906	2,118	57.2
Egypt	1,389	0	1,389	100.0	1,453	0	1,453	100.0
France	1,728	21,895	23,623	7.3	5,527	19,545	25,072	22.0
Germany	28,981	3,143	32,124	90.1	35,245	2,847	38,092	92.2
Greece	0	604	604	0	0	982	982	0
India	24 707	0	24,707	100.0	32,099	0	32,099	100.0
Italy	-	-	9,864	-	8,289	2,249	10,538	78.7
Japan	833	2,806	3,639	22.9	4,624	506	5,130	90.2
Netherlands	728	1,287	2,015	36.1	-	-	2,250	-
New Zealand	2,104	0	2,104	100.0	2,717	0	2,717	100.0
Norway	1,167	110	1,277	91.4	1,556	292	1,848	84.2
Portugal	523	823	1,346	38.8	636	884	1,520	41.8
Roumania	-	-	1,925	-	-	-	1,979	-
Russia	22,256	10,351	32,607	68.3	27,862	13,956	41,818	66.6
Servie	-	-	359	-	356	134	494	72.1
Spain	0	8,206	8,206	0	0	9,316	9,316	0
South Africa Union	-	-	-	-	9,646	0	9,646	100.0
Sweden	2,390	4,629	7,019	34.1	2,743	5,845	8,588	32.0
Switzerland	2,015	0	2,015	100.0	2,250	0	2,250	100.0
*Turkey (Europe)	1,952	0	1,952	100.0	967	0	967	100.0
United Kingdom	0	21,855	21,855	0	0	23,389	23,389	0
United States	0	193,546	193,546	0	0	240,439	240,439	0
Total				27.6				34.1

*Government owned but privately operated.

and operation both exist, but where many lines held under concessions will later fall into state ownership.

Table XLVIII shows the percentage of railway mileage privately and government owned in 30 countries at the end of the various decades, results that are also shown diagrammatically.

In the year 1910, of the total railway mileage of the world 223,778 miles were government owned, 403,844 miles were privately owned.

In the railways classed in this statement and the above table, wherever the title of railways is vested in the government, even if they are operated by private corporations, whether by lease or concession, the mileage is considered as government owned.

APPENDIX.

Assistance has been rendered by the following and is hereby gratefully acknowledged:

American Locomotive Company
Baldwin Locomotive Works
Comptroller of Canadian Railways
Congressional Library
Interstate Commerce Commission
Library of the Pan-American Union
New York Public Library.

Statistics have been compiled in part from the following:

Archiv für Eisenbahnwesen.

Austria—Statistik der in den im Reichsrathe vertretenen Konigreichen und Landern im Betriebe gestandenen Locomotiv-Eisenbahnen.

Austria-Hungary—Eisenbahnen der Osterreichisch Ungarischen Monarchie.

Australia—Commonwealth Statistics of Transports and Communication.

Belgium—Board of Trade Continental Railway Investigation.

Brazil—Annuaire du Brésil Economique.

Canada—Railway Statistics of the Dominion of Canada.

Canada—Annual Report of the Minister of Railways and Canals.

Colvin—Railroad Pocket Book.

De Danske Statsbaner.

English Railways, Reports and Papers.

France—Statistique des Chemins de Fer Français.

France—Rapports par M. le Ministre des Chemins de Fer.

Germany—Statistik der im Betriebe befindlichen Eisenbahnen Deutschlands.

Great Britain's Statistical Abstract for the Principal and other Foreign Countries.

Halsey—The Railways of South and Central America.

India—Administration Report on Indian State Railways.

International Bureau of American Republics, Bulletin of.

Italy—Ferrovie dello Stato, Statistica dell' Esercizio.

Japan—Annual Reports of the Imperial Railway Bureau.

Lavis—The Gauge of Railways, with particular reference to those of Southern South America.

Moody's Manual.

New Zealand Railways Statement.

Norges Officielle Statistik. De Offentlige Jernbaner.

Osterreichische Eisenbahnstatistik.

Poor's Manual.

Railway Equipment Register.

Schweizerische Eisenbahn-Statistik.

Southwestern Book, The

Spain—Anuario de Ferrocarriles.

Sveriges Statistik—L Statens Jernvagstrofik.

United Kingdom—Railway Returns of England, Wales, Scotland and Ireland to the Board of Trade.

United States Census.

United States—Interstate Commerce Commission Reports.

United States—Miscellaneous Documents of the House of Representatives.

ADDENDUM.

Since the above paper was presented to the International Engineering Congress the author has received through the courtesy of Sr. Santiago Mendez, of Mexico City, the following statistics of railways in Mexico. Distances are stated in miles, weights in tons of 2,000 pounds, and currency in gold dollars (United States), two Mexican pesos being taken as equivalent to one dollar.

MEXICO.

	1870	1880	1890	1900	1910
Miles of line	258	671	6,039	11,346	15,172
Miles of sidings	3	10	106	302	630
Total capital	$6,103,900	18,000,000	75,432,000	121,105,000	314,500,000
Locomotives	15	103	632	783	1,190
Passenger train cars	20	360	935	1,450	1,819
Freight cars	100	300	7,652	13,021	42,150
Total operating revenue	$ 800,000	2,242,500	10,459,500	25,399,000	42,835,000
Total operating expense	$ 660,000	1,693,500	7,081,500	16,725,000	28,551,000
Net operating revenue	$ 140,000	549,000	3,378,000	8,674,000	14,284,000
Total number of passengers	800,000	1,268,038	4,679,298	10,004,267	12,295,546
Passengers carried 1 mile	14,914,000	24,013,000	244,762,000	497,335,000	550,113,000
Receipts per passenger mile	$ 0.0201	0.0167	0.0136	0.0158	0.0173
Tons carried	89,151	296,068	2,919,163	6,579,123	13,047,217
Tons carried one mile	3,770,000	17,302,000	306,440,000	967,073,000	2,207,135,000
Receipts per ton-mile	$ 0.1326	0.1064	0.0271	0.0181	0.0173
Aver. number of employees				28,500	37,890
Compensation of employees				$ 9,000,000	13,050,000
Accidents					
Killed					
Passengers			6	3	17
Employees			42	40	83
Others			73	70	100
Injured					
Passengers			22	42	79
Employees			122	200	389
Others			107	113	160

DISCUSSION

Mr. Stucki. **Mr. Arnold Stucki,*** Mem. Am. Soc. M. E., stated that some railroads were not equipped for a 50-ton capacity car in 1897, when the first 50-ton capacity car was ordered, but the Pittsburgh & Lake Erie Railroad was, and others followed very soon thereafter. At no time since their adoption had the Pittsburgh & Lake Erie Railroad regarded the 50-ton capacity cars as too heavy.

Mr. Churchill. **Mr. Chas. S. Churchill,**** M. Am. Soc. C. E., said that the 60-ton maximum capacity car is in very common use, and has been for years. On the Norfolk & Western Railway there are in use 100-ton maximum capacity cars, equipped with six-wheel trucks. The axle load is thus approximately the same for the 100-ton car as for the 60-ton car, which has a four-wheel truck; that is, about 43,000 pounds per axle, including the weight of the car.

Mr. Lavis. **Mr. F. Lavis,**† M. Am. Soc. C. E. (by letter), stated that the construction of the Panama Canal was made possible only by reason of the efficient organization of transportation which permitted the removal of the vast amount of material from the cut through the backbone of the continent. It is entirely fitting, therefore, that this Congress should review both the development of the railway as the supreme agent of land transportation, its present status, and the state of the art of its construction.

The paper before us permits of little discussion; one can only express admiration for the patience, perseverance and skill necessary to obtain, digest and so clearly set forth such a vast and so complete a mass of statistics covering the whole railway field of the world since the beginning of the railway era.

Those who have attempted, even though in only a modest way, to compile railway statistics of any kind in more than one country will realize the discouraging task of any attempt to make such and so many comparisons as have been made by the author of this paper, and the thanks of the Congress and of all those in any way interested in railroads is due him for the vast amount of work performed and the excellent manner of its presentation.

One cannot help feeling in reading this paper, and especially so if one has any personal experience in obtaining comparative statistics of this nature, that no matter what the shortcomings of the Interstate Commerce Commission may have been, this country is indebted to it for a system of accounting and reports as applied to railways which is unequaled in the world from a practical statistical standpoint. It would seem to be not inappropriate for this Congress to take some steps looking to concerted action among the nations of the world for a unified system of reporting statistics of railways. It may seem to be a difficult task,

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** Asst. to President, Norfolk & Western Ry., Roanoke, Va.

† Consulting Engineer, New York, N. Y.

but it is not beyond the realms of possibility if persisted in, and this paper will form a most excellent working basis for this purpose. Mr. Lavis.

It seems almost invidious to criticize in even the smallest degree such a paper as this, but one cannot fail to note the absence of any reference to the results of electrification of certain sections of steam railways. This it is true does not lend itself to statistical comparison as yet, and the extravagant predictions of fifteen years ago have not been fulfilled, but electric traction within certain limited fields, which, however, are being surely if slowly extended, has been an important factor in certain developments of the present century and its possibilities are so great that no one can foresee the effect they may have on the future of transportation. The writer believes, however, that in a review of the railway field to date this development is of enough importance to warrant notice in this general review as well as in the appropriate special section devoted to this subject.

Mr. William J. Wilgus,* M. Am. Soc. C. E. (by letter), said that the past of the railways of the world, as mirrored in the statistics so painstakingly gathered by Mr. Parsons, displays an enormous growth in mileage and in volume and density of traffic, coupled with a pronounced lowering of cost of service to the communities which they serve. Mr. Wilgus.

While this is true for nearly all of the countries for which figures are given, the most remarkable results are shown for the United States, where the mileage between 1870 and 1910 increased nearly five times; capital invested and operating revenues, seven times; passengers carried one mile, over fifteen times; and tons carried one mile, forty-eight fold.

As the volume of traffic has grown so much more rapidly than mileage, it is evident that density too has mounted, and this conclusion is supported by the fact that passenger-miles per mile during this period have increased between three and four times, and ton-miles per mile, ten fold.

During these four decades there has been a decrease in passenger fares from 3 cents to less than 2 cents per mile, and in the ton-mile rate from 2½ cents to ¾ cent, a drop of some 70 percent.

With a knowledge of these fruits of railroad development in the United States, the question naturally arises as to what the future holds forth for this great agency of civilization. It is not to be expected that traffic will cease to rise in volume even if the past rate of growth henceforth is not fully maintained, and therefore it is certain that large sums will be constantly required for additional and improved facilities, such as multiple tracking, larger and more efficient terminals, safety appliances, betterments in alignment, gradients, track and roadbed, elimination of grade crossings, metal passenger cars, more powerful locomotives, and the substitution of electricity for steam motive power in great centers of population and on limiting gradients.

Hitherto private capital has been freely obtainable for this quasi-public service, but the trend of the times seems to indicate that a marked

* Consulting Engineer, New York, N. Y.

Mr. Wilgus. change is pending, and that steel highways like their humble prototype, the post road and turnpike, are to pass to governmental ownership.

In Europe this movement, already quite well advanced in several countries, appears likely to be hastened by the war, which promises to revolutionize many hoary customs of the past.

In the United States the increased press of governmental regulation, without the sobering accompaniment of financial responsibility, apparently cannot fail to dry up the sources of private investment and force the nationalization of railways in order that they may be extended and improved to meet the needs of the public. In fact the laborious and expensive physical valuation of railroads now under way by the Interstate Commerce Commission, although ostensibly in the interest of rate regulation, would seem to point toward the more practicable purpose of establishing a basis for their ultimate acquisition by the government.

The fear is often expressed that, judging from unhappy results in other countries, the government ownership of the railroads of the United States will result in dangerous political control and in the dry-rot and inefficiency that are always present where initiative, so essential to success in private enterprise, is lacking. The recent disclosures of scandalous breaches of trust in the management of certain prominent railroads have lent force to the arguments of those who reply that the evils that flow from government ownership can be no worse than those that are so patent under private control.

Thus facing the alternatives of continued irresponsible governmental regulation of hectored and financially embarrassed privately owned railways, or their ownership outright by the government, it would seem inevitable that the latter eventually will come to pass; and that this being so, every effort should be made to guide the movement so that justice may be done to those who in good faith have invested their money in the development of the country, and so that a plan may be formulated that will at least minimize, if not remove, the well-known evils of governmental ownership.

If the matter is allowed to drift, in the fond illusion that in some way the *status quo ante* will be restored, the outcome is liable to be the gradual impoverishment of the railways through unfair regulation, accompanied by disaster both to their owners, the investing public, and to the public at large whose well-being is intimately bound up in the prosperity of its systems of transportation. Likewise the drifting policy may result in the belated assumption by the nation of a gigantic task for which it will be totally unprepared.

Summed up, it would appear that the existing antagonism between public regulatory bodies and the private management of railways in the United States is resulting in a deadlock that threatens entirely to stop the flow of capital into needed facilities for a constantly expanding volume of traffic, and that the component of forces is heading toward government ownership, to which the country as yet has not opened its eyes.

Paper No. 72

THE STATUS OF THE RAILWAYS OF NORTH AND SOUTH AMERICA.

By

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INTRODUCTION.

This paper is, from its very nature, largely a compilation of information from many sources, to name all of which would be impossible in the limited space available. Assistance has been freely rendered by the ambassadors and ministers of the foreign countries in Washington and our own representatives abroad. Many railways through their executives and others have furnished direct information, and much has been compiled from official government reports, etc.

It has not been possible to obtain all that was desired in some cases, especially as the war has in many cases caused a reduction of staffs, both on railroads and in other places, which has precluded the possibility of compiling much detailed information. The general observations in regard to the United States of North America, Argentine, Brazil, Uruguay, Paraguay, Guatamala and Salvador, while based on general sources of information, have been verified also by the writer's personal knowledge.

Unless otherwise stated, all amounts of money are quoted in dollars, practically equivalent to United States gold.

General Considerations.

The past decade, covering the opening years of the twentieth century, will probably be looked upon in the future as, in many respects, a period of transition for the railways of both North and South America. This would probably have been the case in any event, but the great European War, which

started at the end of the year 1914, will not unlikely serve to further emphasize a change of considerable importance in the relative status of the principal countries of Europe to those of North and South America, in so far as it may tend to destroy to some extent the great preponderance of surplus capital in Europe as compared with the rest of the world, and bring the United States of North America forward as one of the world centers of finance.

In order to get a proper perspective of the status of the railways of North and South America at the present time, it is necessary to call to mind the fact that in this comparatively new western world, the development of the railways and their extensions into undeveloped territory has been unlike and quite the opposite of the development in Europe, inasmuch as they have been the necessary forerunners of any other form of development, and not the development of existing lines of communication between already established centers of commerce.

The rapid development of the railways of the United States has been dependent to a large extent on foreign capital, though the almost unlimited natural resources of every kind, both of food products and manufactures, have made such dependence more a matter of convenience than compulsion, except in the matter of time. To a smaller extent, this is also true of Canada, but for many reasons, the development of the vast areas of Central and South America has been, and will likely continue to be, nearly entirely dependent on foreign capital, which in the past has been almost wholly European.

During the nineteenth century, the development of the then virgin resources of North America was naturally a more attractive field for European investors than was South America in which, with but few exceptions, stable governments were not established until towards its close, and in which climatic and other conditions were not so favorable. North America and especially the United States is entirely in the temperate zone. It is adapted to the living requirements of the people of practically the whole of Europe, so the great tides of emigration and capital from Europe during the past century flowed toward the northern part of the Western Hemisphere, and at

the opening of the twentieth century, that is to say at the beginning of the decade now under review, the development period was practically closed in North America so far as the opening up of new territory was concerned, and it was entering on the intensive development of the resources, the exploitation of which had already been started.

Also during the nineteenth century, the great source of wealth of North America, and the factor which has principally influenced the lines of its development, has been the surplus production of food products, both pastoral and agricultural, which were exported to Europe, serving as payment of the interest on the borrowed capital and for the luxuries or other goods, which it was necessary or desirable to import.

During the latter part of this period, however, as the manufacturing industries were being rapidly developed, the relative proportion of the population engaged in manufactures and commercial life to those engaged in the production of food likewise increased, so that more and more of its food products were consumed at home, with a consequent tendency towards a diminished volume available for export. Up to the present, the increased area under cultivation has nearly kept up with the demand, but the tendency is toward a decrease in the supply of food products available for export, and an increase of the manufacturing and commercial element of the population. There have been, indeed, actual imports of such products as corn (maize) and beef, and there are many indications of a tendency towards an increase of imports along these lines.

The manufacturing interests of North America have, up to the present, been kept busy supplying the needs of their own country, but their capacity has increased now to the point where they must look for outside markets in order to keep their plants fully occupied, and this also is to some extent forced on the country by the necessity of increasing the volume of exports to offset the imports, and to repay its obligation both of capital and interest to its European creditors.

The growing demand in Europe, in fact all over the world, for food products, and by food products is here meant generally the staples, cereals and meat, has turned all eyes to those areas where they may be produced in abundance, which besides

North America are principally Asiatic Russia, Australia, New Zealand, South Africa and southern South America. This paper is only concerned with the effect of this economic development on the last mentioned area.

Of course, local developments at many points throughout both North and South America will be governed by local conditions, but it is believed that the above indicates generally the main trend of events, which have governed the general development up to the present and which will have the greatest influence in the immediate future. It seems not unlikely that the United States of North America must take a greater and ever increasing interest in the development of South America, and will take a not inconsiderable part in lending financial aid to this end (this even in spite of its own foreign indebtedness), and also, that by reason of this and of the necessity of developing its markets for manufactured products, North American engineers and railway managers will have some voice in the development of its transportation systems on the large scale and with the same economic success which has been so marked in the United States, where the conditions in the past have been much the same as those existing today in South America.

Table No. 1 * shows the length of operated lines of all the countries of North and South America, distributed as to gauge, and showing the lengths in proportion to area and population of each country, and given in the order in which the more detailed descriptions follow. In the paper, the lengths are given in miles for North America and Mexico, and in kilometers for all the other countries, though for this table the mileage has been converted, for the sake of uniformity, to kilometers for all countries. (It may be convenient to remember that the kilometer is approximately equal to 0.62 mile.) This table has been compared with various similar tables, and while it seems almost impossible to obtain accuracy in this matter, the general results are substantially the same, or where they differ, it has seemed that the figures given in this table were more nearly correct. It has seemed advisable to give the number of square miles and number of inhabitants per unit of railway rather than vice versa, as has been usual, as tending to show

* All statistical tables are given at the end of paper.

the area and population tributary to the unit length of railway in operation.

NORTH AMERICA.

Canada.

The notes in regard to the railways of Canada are based largely on articles by J. L. Payne in the Railway Age Gazette of Jan. 24, 1913, and Feb. 6, 1914, and on the official statistics for the year ending June 30, 1913. Many of the comparative statistics cannot be given for the period previous to 1907, as at that time a new system of accounting, similar to that prescribed by the Interstate Commerce Commission in the United States, was put into effect. In passing, it may be mentioned that the methods of operation of the Canadian railways, as well as those of Mexico, are practically the same as those of the United States, and traffic and rolling stock are freely interchanged.

The railways are mostly operated by private companies, but the Intercolonial, 1500 miles, two other lines aggregating 400 miles (all standard gauge), and the Prince Edwards Island Railway, 270 miles, of 3′ 6″ gauge, are owned and operated by the Government.

Canada claims the distinction of possessing the largest single railway system in the world; namely, the Canadian Pacific with 11,600 miles of main line, 15,700 miles of track, and a total capitalization of almost five hundred million dollars, of which only 20 million is bonded indebtedness (July 30, 1913). Perhaps, however, the most striking feature, in connection with Canadian Railways during the past decade, has been their very considerable expansion, and the very active part taken by the Government in promoting this, both by actual construction for its own account and by aid in the shape of cash bonuses and land grants to private companies. Latterly, guarantees, in many cases of both principal and interest, have been the more popular form of aid. The total amount of the subsidies granted up to June 30, 1913, was as follows:

	Dominion	Provinces	Municipalities	Total
Cash	$163,251,469	$ 36,500,015	$18,078,673	$217,830,157
Lands (Acres)	31,864,074	11,697,375		43,561,449
Guarantees	95,486,590	179,473,784		274,960,374

These lands were selling at from $12 to $15 per acre in 1912, and the price has been steadily increasing.

The mileage of new lines under construction, or not yet officially placed in operation on June 30, 1913, was:

Surveyed	6,558
Under Contract	8,591
Completed	3,498
Total	18,647

The most important of the new developments of the past decade has been the National Transcontinental line or the Grand Trunk Pacific, which was started in 1906, and which is now practically completed. It extends from Moncton, N. B., on the Atlantic to Prince Rupert on the Pacific, and is about 3550 miles in length. The eastern half was built directly by the Government, the western half by the Grand Trunk Pacific Railway, for the Government, and the whole, as well as the old existing lines of the Grand Trunk Railway Company in eastern Canada, is to be worked by the Grand Trunk Pacific Railway Company. This line has gradients of 0.4%, and even across the Continental Divide, which is passed at the comparatively low elevation of 3718 ft., this is only exceeded on one short stretch of 20 miles, of 1%, operated as a Pusher Gradient.

A third transcontinental line, The Canadian Northern, has also been developed. The main part of this system at present lies to the northwest of Winnipeg, with an outlet to Lake Superior at Port Arthur; it is being extended westerly, via the headwaters of the Peace River, and through the Fraser River Valley to Vancouver, and has under construction a line to the north of the Great Lakes to connect with lines already owned in the provinces of Ontario and Quebec, which will give it eventually a through line from ocean to ocean.

The most remarkable development has been in the provinces of Saskatchewan and Alberta as far north as Latitude 54, which only a few years ago were thought of as part of the barren Arctic wastes, but which now are known to contain fertile, agricultural land adapted to the cultivation of wheat and the hardy cereals, and which are served by many lines of railway.

A noticeable fact, in connection with operation, is the increased use of fuel oil, less than 2 million gallons having been used in 1912 and over 30 million gallons in 1913. Over 22 million cross-ties were used in 1913 at an average cost of 48 cts. each, as compared with 37 cts. in 1907 and about 28 cts. in 1900. This naturally has increased the number of treated ties. The Canadian Pacific, which, owing to the large land grants, has been in a very strong position financially, has carried out and is planning very extensive improvements of its lines, and is said to be considering the utilization of some of the water power for the operation of its mountain lines by electric traction. It has also undertaken extensive irrigation projects for the development of some of its lands near Calgary, Alberta.

The general condition of the railways is shown by statistical tables 2 and 3.

United States of North America.

It has already been noted that, so far as the railways of the United States are concerned, there are virtually no new areas to open up, or new trunk lines to build. The future development, therefore, will be principally in the extension and improvement of existing systems. The necessity of building lines in the early days as cheaply as possible, in order to develop new areas, has been followed by the necessity of improving them to take care of the ever increasing volume of business. By the close of the nineteenth century, the movement for the improvement of existing lines, by reducing gradients and straightening the alignment, improvements in road bed and equipment, installation of block signal systems, and the consequent possibilities of increase of train loads by the use of heavier locomotives, etc., was well under way, and has continued with little abatement up to within the past few years, when the general financial depression of the whole world, coupled with the somewhat onerous regulation by both national and state commissions, has forced a halt.

There have been some notable applications of electric traction to the operation of portions of steam railroads, but the great expectations for general electrification, indulged in at the beginning of the twentieth century and encouraged by the great success of electric traction for urban and interurban

lines, have not been realized. Indeed the great strides which have been made in the development of increased power and in economy in the operation of steam locomotives make this now seem to be farther away than ever. There has, however, undoubtedly been on the whole, great progress along this line, the details of which must be left for the paper dealing with this subject, it being only necessary to point out here that, up to the present, the substitution has, with a very few exceptions (the section of the Chicago, Milwaukee and Puget Sound across the Bitter Root Mountains being perhaps the most important), been made only in cases where the use of steam was impossible or difficult owing to other reasons than its economy as a medium for the application of power directly to the movement of trains, such as in the operation of great terminals or long tunnels or other special cases. The continued development in increased capacity of locomotives and cars, increased train loads and consequent economies in operation, in which the United States has been the leader, are to be noted, though details are left for the appropriate section dealing with these subjects, as is also the development of all steel cars for both freight and passenger service.

Perhaps the most vital feature to the well-being of the railroads as a whole since the latter part of the last century has been the development of regulation by both state and national commissions. The almost entire absence of any effective regulation, up to nearly the end of the nineteenth century, had been one of the most marked points of difference between the railways of the United States and those of practically the whole of the rest of the world. This, as might be expected, undoubtedly led to abuses of privilege on the part of the railroads, and the consequent reaction when the State and Federal Governments attempted to regain their authority and assert their regulatory rights. There was, however, no trained body of men in existence, nor any available, outside of the ranks of the employees of the railroads, to take up the numerous and greatly involved technical problems, which had and still have to be solved in order to carry out intelligently, and for the best interests of the country, the necessary and really desirable regulation; consequently not only were the heads of these com-

missions, in many cases, appointed from the ranks of the politicians, or were lawyers with little or no practical business experience, and least of all railroad experience, but also, in many cases, the employees and so-called technical advisers lacked the requisite broad training and experience. The result at first, in response to the clamor for regulation, was more nearly like oppression, due to a desire to acquire political prestige as well as apparently to punish the railroads for their past misdeeds which most surely had existed, rather than a desire to provide for efficiency in the future.

Laws of all kinds were passed, ordering certain things in some states which were proscribed or prohibited in others, or which were proscribed by the State and ordered to be carried out by the Federal Government or vice versa. The railroads were forced to accede to frequent demands by their employees for increased wages, and have had to face increases in the prices of much of the material (especially in the important item of cross-ties) which they have had to purchase. In spite of all these increases in the cost of labor and materials required for operation, they have not only been denied permission to increase their tariffs or rates, but in many cases these have been lowered by order of the regulatory commissions. The deficit has been to a large extent met by improved methods and increased efficiency in operation, but the margin of profit has been steadily decreased, until the railroads were forced at last to make a concerted appeal for higher rates. This was denied except in certain minor instances by the Federal regulatory body (the Interstate Commerce Commission) in the early part of 1914, but the exigent conditions, brought about by the war, forced a reconsideration in the latter part of the year, which resulted in a general increase of about 5% in freight rates and some increase in passenger rates.

One quite important development, which has been the direct result of the assumption of control by the Interstate Commerce Commission of the affairs of the railroad, has been the decision to make a "valuation" of their properties. This work was commenced towards the end of the year 1913, and is now beginning to get fairly well under way. It seems to be the intention to keep this valuation up to date, once it is ob-

tained, and to use it as at least a partial basis, if not wholly, for the determination of any questions which may arise in regard to the issue of new capital or securities and as to the reasonableness of rates. There are some signs at the end of the year 1914, that, owing to the realization that the cost of making this valuation will be quite a little greater than was anticipated, and of the fact that the possibility of its application to the solution of rate problems is so vague, there has grown up a feeling of doubt as to its practical utility.

It has been suggested that it might be used as a basis for the actual acquisition of the property of the railroads and their operation by the Government, but it seems probable now that public sentiment is on the whole opposed to this. During the decade under review, there has been carried on a most extensive campaign of publicity, both by the railroads and their critics, through the medium of the many thousands of newspapers and magazines, which circulate everywhere so extensively; and to the writer the result seems to be a general awakening of public sentiment against any idea of government ownership, in favor of efficient federal regulation and rates high enough to insure efficient service and to provide a sufficient return so that new capital will be attracted for the continued development of facilities for handling traffic, together with a recognition of the fact that the prosperity of the country is very intimately related to the prosperity of the railways.

The actual situation of the railways of the United States, however, at the end of the year 1914, is that they have many millions of dollars worth of obligations coming due, which they are finding it difficult to refinance, owing not only to the fact that their greatly decreased earnings do not make the investments attractive, and that the war has caused a contraction of all credits, but also owing to the feeling of uncertainty as to the future attitude of the legislative and regulatory bodies.

For several years past also, the railways have found it increasingly difficult to raise sufficient new capital to carry out urgently needed improvements and enlargements of their capacity for handling traffic. During the period of depression, which has existed for some four or five years past, the lack of capacity has not been felt, but when the inevitable reaction

comes, and the railroads are called upon to handle the increased volume of business which prosperous times will bring, the ensuing congestion will prove a source of expense, which will offset any advantages that the increased business might otherwise be expected to bring. Another economic factor which may develop as a result of the war will be in the partial closing at least of the European markets as sources of capital for these necessary developments, and consequently the necessity of dependence, to a much greater extent, on home resources; and as has already been noted, it may be necessary, or at least very desirable, for the United States to help in the development of the resources of South America.

So far as the railways are concerned, the financial problem is one of not a little importance. It is possible that the continuance of the war may result in the extra stimulation of American manufacturing industries, and to meet such demand will require the investment of capital. To transport the products, the railroads must have facilities, the provision of which will in turn require still more capital. The solution of this problem will require the most skillful handling and the cooperation of all concerned, bankers, merchants, and capitalists, as well as railroad managers; but it is believed that it can be solved under careful, consistent and wise regulation of the Federal Government untempered by socialistic or too radical tendencies. The general situation, so far as regulation is concerned, is well summed up in the report of the President of the Pennsylvania Railroad to the stockholders in his annual report for the year ending June 30, 1914. He says, "The loss of control by the railroads of working conditions, the regulation of wages, and the transportation rates, as a result of Federal legislation, has become a practical fact. It is difficult to escape the conclusion that some way must be found whereby the serious but divided responsibility of governmental regulation of rates, wages and other railway matters shall either be concentrated under one administrative branch of the Government, or the results of legislative acts, orders of commissions and awards of arbitration boards shall be recognized by rate regulatory commissions, so that regulation of rates, wages and other mat-

ters may continue, without working a manifest injustice to the railroads and to those who have invested in their securities''.

Table No. 4 shows the general growth of the railways of the United States for the decade 1902-1912, the latter being the last year for which official statistics are available. It is to be noted, however, that while the general growth of the railways has continued during the two years since that time, it has been in a much lessened degree, and the net returns have been very greatly reduced, leading to the situation outlined above. The gradual improvement in the net returns, as shown in the table by the increase in dividends, has not been continued, and while the average rate of wages had increased to $2.49 in 1913, the average freight rate per ton mile had been reduced to 0.727 cts., the trend for the four years 1911-14 being shown by the following table, the data being given per mile of line.

Year.	1914	1913	1912	1911
Total operating revenues	$13,267	$13,730	$12,605	$12,580
Net " "	3,709	4,216	3,888	3,955
Operating income*	3,094	3,669	3,360	3,476

During the year 1914, the increase in the mileage of new lines built was only 1532 miles, the smallest amount since 1895, and the first year when the new mileage in Canada was greater than in the United States. For comparison it may be noted that the greatest mileage of new lines in the United States was 6026 miles in 1902.

The number of locomotives built in 1914 was 2235, as compared with 5332 in 1913, and the number of freight and passenger cars 108,232 in 1914, as compared with 210,980 in 1913.

Alaska.

The comparatively rapid development of Alaska during the past fifteen years, due to the discovery of gold in the Yukon Valley, etc., has resulted in the construction of some 466 miles of railway, about 300 miles of which are standard gauge, the rest narrow gauge. The first line (the White Pass and Yukon) has 20 miles in Alaska and about 82 in Canada; it was built in 1898-1900. The most important line is the Copper River and

*Taxes deducted, other income added.

Northwestern from Cordova to Kennicott, a standard gauge line of very substantial construction, 195 miles in length.

Other lines are:

Alaska Northern-Seward to Turnagain Arm	72	miles
Tanana Valley Railway (narrow gauge)	46	"
Seward Peninsular Railway " "	—	
Council City and Solomon River Railway	33	"

The question of the proper development of the vast mineral resources of Alaska, coal of good quality and copper, as well as the precious metals, led to various investigations by the Government of the United States, and finally, as the result of the report of a commission appointed by President Taft in 1912, an act of Congress was passed, which authorized the President to proceed with the construction of 1000 miles of railways at a cost estimated not to exceed $35,000,000; $1,000,000 was actually appropriated, and during the summer of 1913, preliminary studies of some of the proposed routes were made. It now seems probable that surveys will be continued in 1914 and construction started at an early date.

Newfoundland.

The railways of this colony of Great Britain are 3′ 6″ gauge. The first line was built in 1880, and construction has progressed since then up to the present total of 724 miles. The lines are owned by the colonial government and leased to and operated by a private corporation.

Mexico.

The total length of lines in operation, up to June, 1914, was approximately 12,000 miles, of which about 1200 miles were narrow gauge and the rest 4′ 8½″. The narrow gauge lines are generally feeders and short lines to mining districts in the mountains, but one of the trunk lines from the United States to Mexico City, the Mexican National, was built originally narrow gauge and afterwards changed to 4′ 8½″. The oldest line in Mexico dates from 1854, but the principal development has been since 1880, and was practically coincident with the administration of President Diaz. It was largely influenced by North American interests and capital.

The most important development during the past decade was undoubtedly the acquisition, in 1908, of the control of

approximately two-thirds of the mileage by the Federal Government. It is stated that the idea of this merger originated with the group of North American capitalists who then controlled the Southern Pacific-Union Pacific Systems, but that fear of control of the extensive transportation systems of the country by foreign interests led the Mexican Government itself to adopt and carry out the idea. The method adopted was practically that of the formation of a holding company (The National Railways of Mexico), the common stock of which was ''water'' or ''bonus stock'', but which carried the voting control. This scheme gave the government virtual control without the investment of capital, but there were provisions in the agreement which appear to secure the interests of the stockholders in the constituent companies, whose money still remained as the invested capital.

The revolutions of the past three years have of course stopped all progress and new construction; much damage has been done to the lines, traffic has been frequently suspended, and the future is uncertain.

The following information and data are taken almost entirely from Poor's Manual for 1914.

The National Railways of Mexico operate some 8000 miles (387 miles of which are narrow gauge). The lines of this system extend from the border of the United States on the north, to Guatemala on the south, with branches to Tampico, Vera Cruz and all important cities. This system is a consolidation of a number of lines built by private enterprises, which were taken over in 1908, and at various times since, by an arrangement for exchange of securities, which gave the Federal Government virtual control (with some limitations) of the operation of the lines.

The operating statistics of part of the system for the years ending June 30, 1909 and 1913, are as follows:

Year	1909	1913
Length	5,227	6,089
Passengers, 1 km.	579,000,424	747,511,071
Tons, 1 km.	1,979,734,017	2,006,856,051
Gross earnings (Mex.)	$48,805,522	$57,370,282
Expenses "	$29,166,893	$36,243,947
Net "	$19,638,629	$21,126,335

Dividends amounting to 4% per annum were paid on the first preferred stock up to February, 1913, but none since. No dividends have been paid on the second preferred or common stock, of which two latter there are about 200 million pesos outstanding (1 peso = 45 cts. gold).

The most important of the lines comprising this system are the following:

Mexican Central
National of Mexico
Mexican International
Interoceanic
Vera Cruz and Isthmus
Mexican Southern
Pan-American

The most important of the other lines are the following:

The Mexican Railway Company, built 1865 to 1870 from Vera Cruz to Mexico City, is one of the oldest lines. It operates altogether 374 miles. It had a total annual revenue of about $8,000,000 (Mex.) and operates for about 50%.

The Tehuantepec Railway, crossing the Isthmus of Tehuantepec, was rebuilt by the Mexican Government about 10 or 12 years ago, and extensive port works constructed at its terminals, with the idea of developing a short connecting route between the Pacific and Atlantic Oceans.

The Southern Pacific Company has built nearly 1000 miles southerly from Nogales, Ariz., through Guaymas, down along the western coast.

The United Railways of Yucatan operate some 500 miles in the State of Yucatan, from Merida. Operations for the year ending December 31, 1911, showed the following results:

Passengers carried	1,056,189
Tons freight	381,719
Gross earnings	$3,003,940
Expenses	$1,758,035

THE PAN-AMERICAN RAILROAD.

A discussion of the status of the general railroad situation in North and South America would hardly be complete without reference to the project for a continuous line of railway uniting all the countries of the two continents, which was one of the

results of the Pan-American Congress held at Washington in 1889-90. Surveys (detailed reconnaissance) were made during the years 1891 to 1893, and maps and profiles of the route selected for a line from Southern Mexico to Chile and the Argentine were published in 1898 with the final report of the Commission, which had been appointed to carry out the work. The cost of the surveys and report was borne by the countries represented at the Congress, in proportion to the numbers of their respective populations.

At the Third International American Congress held at Rio de Janeiro in 1906, a permanent Pan-American Railway Committee was appointed, which made a formal progress report to the Fourth Congress, held at Buenos Aires in 1910, which report, in summing up the general situation at that time, showed that between Washington, D. C., and Buenos Aires in the Argentine there were

Constructed	6,012.9	miles
To be constructed	4,198.6	"
Total	10,211.5	"

The report concluded with the following paragraph: "The indications now are that the time is drawing near when men of large affairs, capable of financing such a project, will undertake the building to completion of the Pan-American Railway. Within four years, it is promised that the oceans will be joined at Panama. If the present favorable indications have not been misjudged, an all-rail route should join Panama with Mexico and Washington in 1915, and with Buenos Aires, Santiago and Rio de Janeiro, a few years later".

In spite of the optimism of this report and the tone of the resolutions of the various congresses it seems somewhat unfortunate that continuous effort should be made to show that the actual construction of such a line, as a through transportation route, is a practical commercial possibility or even desirable at present. It is eminently desirable, of course, that the interested countries be kept in mind of the fact, that so far as may be feasible in the natural development of their transportation systems, such lines should follow routes and adopt standards of construction, which will eventually allow them to be made

part of this through line of communication. It is, however, the firm belief of the writer that the advocacy of the commercial practicability of this route, as a line of through transportation, will not only discredit the promoters as practical business men, but that it will be, in many cases, a detriment rather than a benefit to the countries through which it may pass, inasmuch as money spent on this project will, by that much, delay the construction of the very many other lines of transportation, far more urgently needed. (See also notes in regard to the Chilean Government railways.)

It may be pointed out, in regard to the statement quoted above, showing that approximately 60% of the total distance between Washington and Buenos Aires has already been built, that 40% of the total is in the United States and Mexico, and the other 20% is nearly all in Peru, Bolivia and the Argentine, this latter 20%, however, being made up almost entirely of lines which hardly pay operating expenses. The 4000 mile stretch, comprising the other 40% yet to be built between Guatemala and Peru, lies for almost its entire length through the most difficult country and along lines, which, at least for the present, hold out no hope of commercial development on a scale which warrants much of the necessary expenditures, or even offers reasonable prospects of furnishing sufficient business to permit the earning of operating expenses.

That eventually, of course, the railway lines of all the various countries will be so extended and connected up, that there will be a continuous line of railroad from Alaska to Cape Horn, no one can doubt, but that this will only be by the natural process of development, seems equally sure.

As a practical, main, through transportation route from the United States to South America, the project is entirely visionary so far as may be judged with our present knowledge of methods of transportation or in view of any future possibilities which it now appears reasonable to expect. Even if such a line as has been contemplated were in existence today, transportation of both passengers and freight between North and South America at least, and also between many or most of the individual countries, could be carried on much more comfortably, cheaply and expeditiously by water.

In the north, the railway lines of Canada, the United States and Mexico are united and permit continuous through transportation without break of bulk, from northern Canada to the boundary between Mexico and Guatemala on the south. The lines of this latter country, though of different gauge, have been extended to meet those of Mexico, and there is reasonable assurance that within the next five or six years, there will be a through communication from Guatemala, through Salvador and Honduras to Nicaragua.

In the south, the lines of the Argentine and Chile extend to their northern boundaries. The lines of the latter connect with the railways of Bolivia, and only a short gap remains to connect those of the former. The railways of Bolivia connect on the north (by steamer route across Lake Titicaca) with those of southern Peru. Buenos Aires has through rail connection with Asuncion, the capital of Paraguay, and the railways of Uruguay connect with those of Brazil, permitting through transportation from Montevideo to Rio de Janeiro. Within a reasonable length of time, probably easily within the next ten years, the lines in both Paraguay and Brazil will connect with the existing lines in Bolivia.

It seems unlikely, however, that any of these routes (with some few exceptions), excepting those presenting the lines of least resistance fom the interior to the coast, can become through transportation routes in the sense that the main transcontinental lines of the United States and Canada are.

Gauge.

The above conclusions are based wholly on economic considerations, and are entirely apart from the fact of the differences in gauge. Canada, Mexico and the United States, like Europe, long ago adopted 4′ 8½″ as the standard. Central and South America, with some notable exceptions, seem to have been carried away by the fallacies of the narrow gauge. This, perhaps, would not have been so bad, in spite of the fact that anything less than 4′ 8½″ is inadequate for the transportation system of a continent, except that the narrow gauge varies not only with each frontier, but often within the borders of a single country (Chile has lines of eight different gauges), the most common widths being 2′ 6″, 3′ 0″, 1 m. (3′ 3⅜″) and

3′ 6″, so that through transportation, even where the rails reach the various borders, can only be a sentimental vision, unless some concerted action can be taken to overcome this difficulty. This phase of the question seems to have been entirely overlooked by the advocates of the Pan-American Railway as a through route.

For the present, this question of gauge is most serious, as it affects the development of southern South America in the vast plain which stretches practically from Patagonia to the Amazon and from the Andes to the Atlantic. The Argentine is struggling with three gauges; Uruguay and Paraguay have the standard, 4′ 8½″; and Brazil has mostly 1 meter, a gauge wholly inadequate for the development of its vast territory, with bulk freight to be hauled long distances at low rates. This subject has, however, been treated of *in extenso* by the writer,* and is, therefore, only mentioned as a matter of vital interest, in connection with the present operation and future development of the railways of this section.

CENTRAL AMERICA.

Guatemala.

The railway lines of Guatemala (except the Verapaz Railway, 40 km.) are now all consolidated under the management of the "International Railways of Central America", which also controls certain other lines and concessions in Salvador and Honduras. The system comprises essentially an east and west line across the country from Puerto Barrios on the Atlantic, via the capital, Guatemala City (elevation 4910 ft.) to the Port of San José on the Pacific, with a line running northerly from near San José along the Pacific coast to the border of Mexico. The consolidation was completed in 1911, the original constituent lines being as follows:

	Length Miles	Date of Construction
Guatemala Northern	194.9	1892-1907
Guatemala Central	138.6	1878-1903
Occidental	51.1	1884-1899
Pan-American Extension	40.0	1910-1914
Ocos	23.0	1896-1899
	447.6	

* Transactions, American Society of Civil Engineers, Vol. LXXVIII (1915).

There are approximately 48 miles of sidings and yard tracks in addition to the above.

Practically all these lines have received substantial subsidies in cash or lands or both. For the Guatemala Northern, the Government guarantees the deficit, if any, between the net earnings and 5% interest on $4,500,000. The gauge is 3′ 0″. The gradients on both the Guatemala Northern and Guatemala Central are 3.6% on approximately one-third of their lengths, and there is considerable curvature on the mountain sections, with maximum curves of 19 degrees (300 ft. radius).

The equipment of the combined lines is as follows:

Locomotives	71
Baggage and Mail cars	21
Passenger cars	93
Freight "	1,354
Service "	48

The comparison of the financial returns from these lines, over any extended period, is difficult owing to the many changes in management and various methods of accounting, fluctuation in the value of currency, etc. There has been, however, a very decided increase in earnings during the past few years, due to quite a large extent to the development of the Motagua Valley for the cultivation of bananas and to the efficiency of the management. The following table is in United States Gold:

	1906		1913	
	Earnings	Expenses	Earnings	Expenses
Guatemala Central	$821,927	$501,351	$806,977	$388,645
	1908			
Guatemala Northern	317,903	291,135	1,469,478	674,221
	1912			
Occidental	161,316	96,797	178,382	94,506
	1912			
Ocos	133,818	48,995	149,972	62,058
Total 1913			$2,604,809	$1,219,430

This, it will be noted, gives the very low operating ratio of 46.8% for 1913. The totals for 1914 will probably be lower, owing to the effect of the war in decreasing the value of the coffee crop, the main source of revenue of the country. The

value of the above lines, with equipment, is carried on the books at $46,592,400. The Pan-American Extension to the Mexican border was completed at the end of February, 1914.

Traffic statistics for the Guatemala Northern and Guatemala Central for 1913 are as follows:

	Northern	Central
Number of passengers	184,437	540,747
Passenger miles per mile	30,036	80,248
Revenue per pass. mile cts. gold	2.2	2.9
Tons of freight	171,281	184,587
Ton miles per mile	70,313	54,723
Revenue per ton mile cts. gold	7.56	5.91

The maximum tariff rates of the Guatemala Northern are as follows:

Passengers 1st class	6 cts. gold per mile
" 2nd "	4 " " " "
Freight ton (2,000 lb.)	20 " " " "

New Developments.—The completion of the so-called Pan-American Extension, permits through rail connection between the railways of Guatemala and the United States through Mexico, except for the break of gauge. A concession has been granted to the Guatemala Northern for a line from Zacapa to Salvador, which it is proposed to extend eventually, via the City of San Salvador, to La Union at its southern boundary on the Gulf of Fonseca. The southern end of this line has been built for about 70 miles from La Union northerly to Usulutan, and construction is being continued. Surveys have been made of the northern part from Zacapa in Guatemala, to Santa Ana in Salvador.

This theoretically links up the railway systems of Salvador and Guatemala with Mexico, the United States and Canada, but so far as this may be considered a through route, the idea is not to be considered practical at present; the natural outlet for both of the countries when these lines are completed being via Puerto Barrios on the Atlantic coast of Guatemala.

Salvador.

There are three lines in operation in Salvador having a total length of about 260 km., all 3′ 0″ gauge.

The Salvador Railway, operated by British interests, runs from Salvador City to the Port of Acajutla (105 km.), with a branch from Sitio del Niño to Santa Ana (38 km.). It has grades of 3.8%, and curves of 20 degrees. Construction was started in 1880, and about twenty miles were built up from the coast by 1890. The line was finally completed to Santa Ana in 1896 and to San Salvador City, the capital, soon after.

The Salvador Railway is capitalized at $7,000,000. The gross revenue for the five years, 1904-5 to 1909-10, varied from about $450,000 to $530,000 per annum, and the operating ratio from 50% to 55%. The above does not include a subsidy of about $115,000 per annum, payable by the Government up to the year 1917. The gross revenue for 1913 amounted to $782,000 (probably including the subsidy). About 75% of the revenue is from freight, the largest single item of which is coffee. The company operates a line of steamers from Acajutla to Salina Cruz the Pacific terminus of the Tehuantepec Railway.

Rolling Stock— 12 Locomotives
23 Passenger Cars
172 Freight Cars

The maximum tariffs allowed by the concession are:

Passenger 1st class	4	cts.	gold	per	mile
" 2nd "	2	"	"	"	"
Freight ton (2,000 lb.)	13	"	"	"	"
Coffee	12.2	"	"	"	"

The Santa Tecla Railroad (under local control) has had gross earnings, varying from $75,000 silver in 1897 to about $30,000 in 1907, and operates at about 50% (silver 40% in 1911). Its length is 13 km. Gauge 3′ 0″.

Rolling Stock— 3 Locomotives
6 Passenger Cars
3 Freight Cars

A concession was granted in May, 1914, for the extension of this line to the port of La Libertad, the Government guaranteeing 5% interest and 1% amortization on bonds, issued at par to cover the cost of construction and for a total not exceeding $1,500,000 gold. There is also a tentative provision

for a branch from the lower end of this line to Zacatecoluca. When necessary, a part of the customs dues is to be set aside to provide for these payments.

The International Railways of Central America, a United States corporation, controls the concession for a line from La Union (a good harbor on the Gulf of Fonseca), via Salvador City, to the border of Guatemala, where it is to connect with the line to Zacapa (see Guatemala). The construction of the lower part of this line from La Union to San Miguel was started by the Government in 1900, and, after being nearly completed, was abandoned. This portion was reconstructed and completed in 1911-12, and the line is being extended northerly at the rate of about 20 km. a year. It reached Usulutan (km. 105) toward the end of 1913 and work is being continued towards the Lempa River.

Rolling Stock—	6 Locomotives
	8 Passenger Coaches
	38 Freight Cars

This concession carries a subsidy of $7000 gold per km. payable (on the completion of each 10 km.) in bonds at 90 with 5% interest and 2% amortization (guaranteed from customs). Rates allowed are substantially the same as Salvador Railway. The Supreme Court of the United States is named as final arbitrator of disputes.

The investment in this line to Dec. 31, 1913, is given as	$1,300,341
Less subvention	534,314
Net	$ 766,027

Honduras.

All the existing lines are on the Atlantic side.

The National Railway is owned and operated by the Government. Its length is 90 km., gauge 3′ 6″. It runs from Puerto Cortez to Pimienta. The external debt of the Republic was incurred for the construction of this line.

Earnings 1913—

Gross	600,000 soles
Expenses	450,000 "
Net	150,000 "

Tariffs—

Passenger 1st class	5 cts. silver per km.
" 2nd "	3 " " " "
Freight per ton	1 to 4 cts." " "

Carload lots half the above.

Rolling Stock—

10 Locomotives	21 to 49 tons
10 Cars	20 tons capacity

Tela Railroad. The United Fruit Company has surveys for a line from Pimienta, via the valley of the River Ulua, to Tela. Construction has been started on this line (Oct., 1914). Gauge 3′ 6″.

Rolling Stock— 7 Locomotives
112 Flat Cars, 30 tons

The Ferrocarril Vaccaro is a line built and operated by a fruit company inland from La Ceiba. In 1912-13, there were 114 km. of main line and branches, of which 23 km. had been built during the past year. Gauge 3′ 6″.

Rolling Stock— 7 Locomotives
6 Passenger Coaches
205 Freight Cars

The Cuyamel Fruit Company has 57 km. of 4′ 8½″ gauge built (1911-14) and 40 km. 30″ gauge tramways, all for development of its plantations near Puerto Cortez.

Rolling Stock— 6 Locomotives, 8 to 36 tons
110 Freight Cars, 25 tons

There are also the following:

Colorado Railroad (United Fruit Company) 27 km. from La Ceiba.

Honduras Rubber Company, 5 km., at Nueva Armenia.

Tropical Timber Company, 8 km., to build ten more.

Pan-American Line. The International Railways of Central America has a concession for this line, to run from a connection with that company's lines in Salvador along the Pacific Coast to the border of Nicaragua, and for a line from the Pacific Coast to Tegucigalpa, the capital. Surveys of this line are being made.

Trujillo Railroad is 37 km. in length, under construction, track laid; 4′ 8½″ gauge, 4 locomotives, 50 cars, not opened for traffic Sept., 1914.

British Honduras.

The Stann Creek Railway has 40 km. of line, owned and operated by the Government (Crown Agents for the Colonies —Great Britain), 3′ 0″ gauge.

Rolling Stock— 4 Locomotives
48 Freight Cars

Nicaragua.

The principal railway is the Ferrocarril del Pacifico de Nicaragua. It is 278 km. in length, 3′ 6″ gauge. It runs from the harbor of Corinto on the Pacific Coast to Managua, the capital, and to Granada on Lake Nicaragua. Most of it was built prior to 1900.

It was owned and operated by the Government up to the end of June, 1913, when 51% of the stock was bought by New York bankers, who are now directing the operation. The following statistics, for the year ending June 30, 1914, are approximate only:

Gross earnings	$561,458
Expenses	307,737
Net	253,722
Passengers	812,500
Passengers km. per km. line	101,900
Revenue per pass. km.	0.6 cts.
Freight tons	98,600
Ton km. per km. line	83,500
Revenue per ton km.	1.6 cts.

Costa Rica.

The Northern Railway Company of Costa Rica operates all the lines, part of which (about 340 km.) are leased from the Costa Rica Railway Company, a British corporation, and about

100 km. from the Government. Railway construction was started in 1871, and the Costa Rica Railway was built from Puerto Limon to the capital, San José. Recent developments have been largely in connection with the cultivation of bananas near Port Limon by the United Fruit Company, with which interests the Northern Railway Company is identified. The railway systems now form a continuous line of communication between Puerto Limon on the Atlantic, by two routes to San José and thence to Punta Arenas on the Pacific. The gauge is 3′ 6″. The operating results for 1910 were as follows: (official)

Miles operated		357
Gross earnings, gold	$2,396,307	= $6,712 per mile, gold
Operating expenses, gold	1,714,162	= 4,801 " " "
Net earnings, gold	682,145	= 1,911 " " "
Operating ratio	71.5%	
Tons one mile	14,406,174	
Rates per mile—		
Per count, bunch bananas		$ .00446
Per ton freight		$ .13293
Per passenger		$ .03260

Panama.

Statistics Panama Railroad, Year Ending June 30, 1913, from Annual Report.

Items—	1912	1913
Average length operated km.	82	100
Gross operating revenue	$4,541,488.90	$4,599,163.13
Operating expenses	2,655,121.51	2,770,310.45
Net operating revenue	1,886,367.39	1,828,852.68
Percent expenses to revenue	58.46	60.24
Gross revenue per mile	89,416.99	74,203.99
Operating expenses per mile	52,276.46	44,696.84
Net revenue per mile	37,140.53	29,507.15
Tons per loaded car	22.26	23.63
Tons per train	295.23	353.21
Tons of company freight	54,157	77,637
Tons of revenue and company freight carried one mile	73,435,639	83,085,155
Average mile each ton revenue freight was carried	39.41	41.37
Revenue per ton per mile	3.99	3.48
Tons of revenue freight carried one mile per mile of road	1,409,679	1,301,088
Passengers carried	2,757,671	2,916,657
" " 1 mile	32,073,043	34,845,129

Items—	1912	1913
Average distance each passenger carried	11.63	11.95
Revenue per passenger per mile	2.30	2.37
Passengers 1 mile per mile of road	631,483	562,199

Rolling stock—1913

61 Locomotives
57 Passenger Cars
1,039 Freight Cars

Note: The majority of the stock of the Panama Railway Company is now owned by the Government of the United States, control having been bought, incidental to the construction of the Panama Canal. The above figures apply only to the railroad, and do not cover revenue, etc., from the steamship lines, etc., which the railroad company operates. The indications are that the statistics for the year ending June 30, 1914, will show little change from those for 1913 quoted above.

It had been proposed to use some of the money received from the United States on account of the construction of the canal to build a narrow gauge line from Panama (Empire station on the Panama Railroad) to David, more or less along the line proposed for the Pan-American Railroad. This scheme, however, was abandoned in favor of building several short lines, aggregating in all about 200 miles, inland from the Pacific Coast. Construction was started during 1914 on the Chiriqui line.

WEST INDIES.

Cuba.

Railway construction in Cuba received a decided impetus during and subsequent to the period of intervention by the United States (1899-1902), as is shown by the following table giving the lengths of line in operation.

1898	1,787 km.
1901	1,788 "
1904	2,333 "
1907	2,986 "
1909	3,197 "
1913	3,798 "

The above gives the length of main line and branches, and in addition, there are numerous sidings and private branches into the sugar estates, which in 1909 amounted to an additional

500 km. None of the figures given include the industrial tracks and private lines of the sugar estates.

The standard gauge is 4′ 8½″. The following table shows the distribution of the lines of different gauge in 1913.

	5′ 0″	4′ 8½″	3′ 0″	2′ 6″	2′ 3½″
Km.	73	3,410	118	111	86

The ownership is largely British, as is indicated by the following partial tabulation (1913). No lines are owned or operated by the Government.

British	1,955	km.
United States	1,082	"
Cuban	340	"

This, it will be noted, leaves about 400 km. unaccounted for. There are twenty-one different lines shown in the tabulation for the year ending June 30, 1913. Some data of the standard gauge lines over 100 km. in length for that year are noted below.

	Length Km.	Cost	Gross Income	Expenses
United of Havana	1,138	$49,103,837	$7,905,636	$4,301,461
Cuba Railroad Co.	950	37,257,132	4,632,040	2,399,584
Cuban Central*	565	18,880,024	2,995,374	1,707,111
Western of Havana*	238	8,470,010	1,363,135	804,100
Guantanamo and Western	130	6,482,419	440,774	383,140
Havana Central*	110	16,419,605?	856,011	535,492

Amounts given are gold values.

The United of Havana was formed by the consolidation of three lines in 1907 and the construction of about 100 km. of new line since then. **The Cuba Railroad** is mostly a new line built by American and Canadian interests, through the center of the island, from Havana to Santiago. **The Cuban Central** was formed by the consolidation of three lines in 1901, and some extensions made during the last three or four years.

A railroad law and regulations, based largely on United States practice and law, was put into effect during the occupation by the United States in 1902.

*These three lines have been purchased by the owners of the United Railways of Havana, but they still continue (and will continue indefinitely) to be operated under the old company organization.

A law was passed in 1908 requiring the equipment of all rolling stock with automatic couplers (M.C.B. type) and air brakes. All the new lines and new rolling stock were already so equipped, and in 1909, only a small proportion of freight cars remained unchanged, all of which were to be equipped in eight years from that date.

The averages given below are for all the lines, though some of the shorter ones carry no passengers and some, no freight. They, however, are so small as not to materially affect the general results.

	1904	1913
Total receipts	$7,798,876	$20,354,171
Total expenses	4,724,625	11,519,673
Operating ratio	60.6%	56.6%
Net revenue	3,074,251	8,834,498
Km. of line	2,333	3,798
Net revenue per km.	$1,318	$2,326
Estimated total cost		155,186,712
" " " per km.		40,860
Average return on investment		5.7%
Bonded indebtedness		82,121,900
Number of locomotives	274	476
" " passenger cars	532	535
" " freight cars	6,762	13,366

	1904	1909
Number of passengers 1 km. per km. line	51,441	69,056
Average distance per passenger km.	24.8	27.6
Average receipts per passenger per km. cts.	1.77	2.03
Freight tons 1 km. per km. of line	105,347	102,015
Average distance per ton	45.9	39.4
Average receipts per ton per km. cts.	2.06	2.21

Train Loading. The available statistics do not permit comparison of all the lines, but the data for some of the most important (about 80% of the mileage) show a general tendency towards increased economy in operation by increases in both the train and the car loadings.

	Tons of Cargo per Train		Av. Tons of Cargo per Loaded Car	
	1904	1909	1904	1909
Western of Havana	62.8	110.9	6.2	9.1
United	75.0	93.7	7.0	9.8
Cuba Central	79.3	78.6	14.8	11.3
Cuba Railway	58.0	86.0	8.4	11.3
Cuba Eastern	15.8	25.0	4.8	6.6

Jamaica.

The first railway, 12 miles in length, was built in 1844, and in 1885, there were 64 miles in operation. Total length, 1914, is 198 miles; 4′ 8½″ gauge; owned and operated by the Government. It has grades of 3.3%, and curves of 330 ft. radius.

Earnings 1910-11 (on 184½ miles).

Gross about	$785,500	(American gold)
Expenses about	$505,190	" "
Total cost (184½ miles) about	$12,500,000	gold

Short branch extensions are being built from time to time.

Porto Rico.

The principal railroad is a meter gauge line, which runs from Carolina (branch to San Juan) along the north, west and south coasts, around the island to Ponce. It was built under a concession granted by the Spanish Government in 1886, and is now operated by the American Railroad Company of Porto Rico, a North American corporation. The length of the main line is 203 km., and there are numerous branches. There are also a number of other lines, as shown by the following table, showing all lines, all meter gauge (1914).

American Railroad Company, main line and branches	330 km.
Fajardo Development Company	40 "
Vega Alta Railroad	11 "
Humacao Railroad	11 "
Bianchi Railroad	11 "
Caguas Tramway Company	29 "
Bayamon Railroad (Western)	5 "
	437 "

	Locomotives	Passenger Cars	Freight Cars
American R. R. Co.	51	52	1,300
P. R. Lt. & Power Co.	2	35	10
" " " "	16	6	200
Western Railway	3	7	25
	72	100	1535

Hayti.

The Central Railroad of Hayti, in addition to the wharf and electric light plant at Port au Prince, operates the lines

of the Compagnie des Chemins de Fer de la Plaine du Cul de Sac, having a total length of 103 km., 30″ gauge, in and around the city of Port au Prince. This includes the tramways of that city, operated by steam locomotives. The lines were built between 1901 and 1910.

Rolling stock—18 Locomotives, 8 to 38 tons
31 Passenger Cars
60 Freight Cars

Earnings 1906 to 1910 from $30,000 to $50,000 per annum.

1911	82,376
1912	126,340
1913	75,355

Operating expenses are usually more than receipts. The government, by the terms of the concession, guarantees operating expenses and a subsidy of $41,280 per annum. The latter has been paid, but the deficit in operating expenses has not.

The National Railway of Hayti, operating under a concession granted in 1910 for building 640 km. of main line and branches between Port au Prince and Cape Hatien, gauge 3′ 6″, has built about 280 km., of which, 108 were placed in operation in 1913, but suspended early in 1914, owing to a disagreement with the Government. The Government guarantees 6% interest on bonds issued for construction purposes, to the extent of $20,000 per km. Bonds to the amount of $3,500,000 were issued, of which $2,500,000 were sold in Paris, the rest remaining in the hands of the North American bankers, who undertook the construction. The Government refused payment of the last installment of interest, and the payment, falling due August 1, 1914, was defaulted.

Numerous changes in the Government prevent active development of an otherwise rich region which should, and, with favorable conditions, would furnish ample revenue to both these roads and further extensions.

Santo Domingo.

Dominican Central	97 km.	2′ 6″	gauge	(Owned and operated by Govt.)
Macoris Railway	11 "	3′ 6″	"	
Samana-Santiago Ry.	129 "	3′ 6″	"	(British)

Project for line from Brahoma to Neybo and to frontier of Hayti, construction on which was reported to have been started early in 1914.

Samana-Santiago Ry. to Dec. 31, 1912

Gross receipts	$377,500
Expenses	146,957
Net	$230,543

Barbados.

Forty-two km., 2′ 6″ gauge, built in 1882; reconstructed since then. Total cost about $1,175,000. Gross receipts $45,000, which includes a subsidy of $10,000. Working expenses $40,000.

Trinidad.

The railways are controlled by the Government; their length is 191 km., of 4′ 8½″ gauge.

Gross receipts, 1911-12, were about $6500 per mile, with operating expenses about 62%.

SOUTH AMERICA.

Dutch Guiana (Surinam).

The only line is operated by the Government. It is 173 km. long, and of meter gauge.

Rolling stock—10 Locomotives
19 Carriages
48 Wagons

British Guiana.

There are three railways controlled by British interests, as follows:

Georgetown to Rosignol	97 km.	4′ 8½″	gauge
Vreed-on-hoop to Greenwich Park	24 "	3′ 6″	"
Wismar to Rockstone	29 "	meter	"

Rolling stock on first two lines—
14 Locomotives
42 Passengers Cars
269 Freight Cars

The gross receipts of the first two lines (75 miles) are about $3000 per mile, with operating expenses about $2500.

Venezuela.

The following information is condensed from a report prepared by the Ministry of Public Works, especially for this paper, and is, therefore, official.

The development of the railways of Venezuela has been practically at a standstill during the past 20 years. Most of the existing lines were built between the years 1881 and 1893, under government guarantees of 7% interest, with little supervision over the expenditures, and practically no limits to the capital accounts. At the end of this period, there was the natural reaction against the somewhat loose methods, which had developed, and very stringent laws were enacted, which practically caused the suspension of all new work.

In 1912, however, a new law was passed with the object of encouraging new construction, under fairly reasonable provisions for the protection of both the government and the investor. A general scheme of development was worked out, and it is hoped that as soon as general financial conditions improve, some work will be started along these predetermined lines.

The new law permits the government to grant cash subsidies, but in no event to guarantee interest. It is also the policy to make grants of land and to encourage colonization. Cash deposits, as guarantees of good faith, are required from concessionaires and with all applications for concessions. Materials of construction may be imported free of duties.

It is of interest to note the difference in the attitude towards guarantees between Venezuela and Canada. In the latter, confidence in the immediate development, and in the future, due to the long existence of a stable form of government and a fair assurance of continuous immigration, makes guarantees attractive to people whose present resources of ready money capital are limited, in comparison with the great needs of a rapidly growing country. In Venezuela, under the guarantee system, the country was almost forced into bankruptcy, by reason of the fact that the developments were far less than the expectations.

Venezuela seems to have definitely committed itself to the narrow gauge system. Many of the existing lines have fre-

quent gradients of between 3% and 4%, and curves of from 40 m. to 50 m. radius. The new regulations, however, provide that on the lines of normal gauge (3′ 6″) the maximum gradients shall not exceed 3.0%, and that the minimum radius of curves shall be 60 m. For the secondary lines of 2.0 ft. gauge, gradients of 3.5% and curves of not less than 30 m. radius are permitted.

The total length of lines in 1913 was as follows:

Gauge Meters	Ft. In.	Operated	Under Construction	Total
0.61	2 0	181.65	54.95	236.60 km.
0.92	3 0	254.78	3.67	258.45 "
1.00	3 3⅜	174.50	5.50	180.00 "
1.07	3 6	336.16	23.00	359.16 "
		947.09	87.12	1,034.21 "

The above includes railways of all kinds and certain lines operated as electric tramways and some small mining lines. The following statistics apply only to the regularly operated steam railroads, of which there are 869 km., and are for the year 1913.

		Bolivars
Total capital		196,748,125
Number of passengers	642,404	
Receipts from passengers		2,457,562
Tons of freight	283,000	
Receipts from freight		10,808,697
Total receipts		13,266,259
Total expenditures		7,069,344
Profit		6,196,915
Ratio		53.3%
Return on capital		3.15%

(The Bolivar is worth $0.193.)

Rolling Stock—

Locomotives	91	Average Weight	31.9 Tons
Passenger Coaches	126	" "	8.5 "
Freight Cars	848	" "	5.5 "

Ownership.

	Km.	Bolivars
Venezuelan government	109.78	9,261,625
" private	195.86	15,000,000
British	335.59	89,486,500
German	178.90	79,000,000
French	54.40	4,000,000
	874.53	196,748,125

Rates (Bolivars).

Passenger—1st class per km.	0.19 to 0.34
" 2nd " " "	0.10 to 0.22
Freight per ton per km.	0.50 to 1.50

Colombia.

The Magdalena River is the main transportation route between the coast and the interior. Bogota, the capital, is nearly 500 miles inland from the Carribean Sea, and at an elevation of 8500 feet; the railways thus far built are generally supplementary to the main fluvial routes.

The following table shows the length of line to have been doubled between 1898 and 1913, but the larger part of this increase was in the first few years of this period.

Statistics Colombian Railways, 1913.

Name of Railroad—	Controlling Interest	Length Km. 1898	Length Km. 1913	Gross Revenue Gold	Gauge
Antioquia	Department	59	169	$517,696	3′ 0″
Amagá	Local		30	97,971	
Barranquilla (Bolivar)	British	28	28	310,046	3′ 6″
Cartagena (Colombia Ry. & Nav. Co.)	British	105	105	215,407	3′ 0″
Cucuta	Government	55	55	211,105	3′ 0″
La Dorada (Honda)	British	33	115	445,220	3′ 0″
Cirardot (Colombia Nat.)	British	39	132	500,174	3′ 0″
Buenaventura (Pacifico)	North America	36	137	24,704	
Puerto Wilches (N. Cent.)	British		20		1 m.
Norte		48	62	261,329	1 m.
La Sabana (Facatativá)	Government	40	40	283,500	1 m.
Santa Marta	British	39	98	509,717	3′ 0″
Del Sur	Government	10	33	74,899	
Tachira		16	16	12,722	
Tolima		7	7		
	Total	515	1,065		

Colombia is very rich in natural resources both agricultural and mineral (including coal and oil), but the development of railway transportation has been slow because of the difficulty of the terrain, the trying climate in many parts of the lower altitudes, and the general political unrest of the last fifteen years. The effect of this latter is shown by the following table, showing the increase in the rate of exchange, especially during the first decade of the present century.

Approximate Average Value of $100.00 Gold.

1870	105		
1880	110		
1890	192		
1898	276		
1900	610		
1901	1,670		
1902	4,310	(approx.)	
1903	10,240	"	Highest 16,500
1913	10,000	"	

The Cartagena-Magdalena Railroad was built in 1892-4 by a North American company, and afterwards sold to British interests, but Colombians have now a considerable interest in the property. It runs from Calamar on the Magdalena River to the protected deep water harbor at Cartagena. **The Puerto Wilches** project was an ambitious one, being intended not only to tap the rich coffee district of which Bucaramanga is the center, but also to provide a through route to Bogota. It was recently stated that the project had been abandoned after building a short length (20 km.) through very difficult country. **The Cucuta Line,** on the border of Venezuela, provides an outlet from a coffee producing district to a river and thence to the Gulf of Maracaibo. **The Dorado and Girârdot lines** connect Bogota with the navigable waters of the Magdalena River. **The Antioquia Railroad** is to connect Medellin with Puerto Barrios on the river. It is being built from both ends. The gap remaining involves a long tunnel or heavy work on a developed line. Considerable German capital has been invested in this line. **The Santa Marta line** has been developed by the banana industry. **The Barranquilla line** runs from the city of that

name to the port of Sabanilla, an open roadstead with a pier. All the lines built have been subsidized.

There are many projects for new lines, nearly all of which carry subsidies, but there has been little activity in recent years, owing to the unstable financial conditions. The principal projects under consideration are:

Medellin to the Gulf of Darien. Subsidy $25,000 per mile and lands.
Rio Hacha to Barrancas 100 km. 1 m. gauge. Land subsidy.
Extension to Pacific line from Cali to Popayan 64 km.
Puerto Wilches.
Barranquilla Interurban Tramway.

Ecuador.

The Guayaquil & Quito (F. C. del Sur) runs from Guayaquil on the coast to Quito, the capital. Its gauge is 3′ 6″, and length 464 km. This line was started in the early 70's, and built to Chimbo. Its construction was again taken up in 1898, and the line completed to Quito in 1908. It has curves of 30 degrees (radius 193 ft.), with grades equivalent to 5.5% on tangents, operated by adhesion. This line is operated by an American company, but the Government has representatives on the Board of Directors.

A Government report for 1914 shows the following results of the operation of this line for the last two years.

	1912	1913
Receipts	2,401,792	2,017,106
Expenditures	2,292,303	2,364,110
Net	+109,489	—347,004

(Above figures sucres. Sucre = $0.487 gold.)

A line, 300 km. in length from Ambato to Curaray at the headwaters of the Amazon, has been projected by the Government, and construction was started under the direction of North American engineers in November, 1912, but shortly afterwards was stopped and has not been resumed. Preliminary surveys have been made for 125 km. Grades 2½%. Gauge 3′ 6″. About 10 km. of track have been laid.

A concession has been granted to a French company for a line in the northern province.

Peru.

The principal railways of Peru were built by the Government, and were taken over in 1890 by the Peruvian Corporation (British), as part of an arrangement for the cancellation of the external debt, which had been incurred largely for the construction of these lines. The original contract to turn over the railways to the foreign bondholders was made in 1879, at which time the debt was about $200,000,000 gold, but at the time they were taken over by the Peruvian Corporation, it had, by reason of accumulated defaulted interest, increased to something over $250,000,000.

The contract, as finally modified, provided that in exchange for the entire cancellation of the foreign debt, the bondholders should receive

The lease of the railroads until 1973 (originally 66 years from 1879),
2,000,000 tons of guano (originally 3,000,000),
30 yearly payments of $400,000 per annum from 1893 (originally 33 payments of the same amount),
right of free navigation on Lake Titicaca,
certain payments from Chile which amounted to about $6,000,000.

The Peruvian Corporation agreed to extend the lines to Cuzco and Huancayo.

The following are the lines now operated by the Peruvian Corporation:

	Gauge	Length Km.	Date of Construction
Peruvian Central (Oroya)	4′ 8½″	399	1870-1910
" Southern (Mollendo)	"	861	1870-1910
Pacasmayo	"	94	1876
Payta-Piura	"	97	1884
Pisco-Ica	"	74	1869
Lima-Ancon	"	38	1869
Trujillo	3′ 0″	120	1896
Chimbote (1 m.)	3′ 3⅜″	57	1872
Ilo-Moquegua	4′ 8½″	100	1873-1910
Total		1,840 km.	

The maximum tariffs allowed on the Central and Southern Railways are as follows:

1st class passenger	6 cts. gold per km.
2nd " "	3 " " " "
Freight per ton	18 " " " "

The operating revenues of the Central and Southern, for 1913, were:

	Gross	Net
Peruvian Central	$2,539,045	$938,890
" Southern	1,783,370	664,833

The traffic on these same two roads was as follows in 1908:

	Passengers		Freight
	1st Class	2nd Class	Tons
Callao to Oroya	475,418	810,848	319,018,813
Mollendo to Arequipa	184,591	290,304	78,105,109
Arequipa to Puno	9,136	14,645	13,058,867

The total receipts from all the lines operated by the Peruvian Corporation have been as follows, the yearly increase having been fairly uniform (gold).

	Gross Revenue	Expenses	Net
1896-7	$1,615,240	$1,165,658	$ 449,582
1906-7	4,290,830	3,150,177	1,140,653

The Peruvian Central (Oroya) Railway, from Callao and Lima over the Andes (elevation 15,583 ft.), was built to Chicla in 1877, completed to Oroya in 1892, and has been extended to Huancayo since 1908. Anticona on a branch is at an elevation of 15,865 ft. **The Peruvian Southern** from Mollendo to Lake Titicaca, with a branch to Cuzco, reaches 14,665 ft. These lines have 4% grades and curves of 100 m. radius, 4′ 8½″ gauge, and are constructed in a very substantial manner. From Puno on Lake Titicaca, there is steamer connection to Guaqui in Bolivia, operated by the Peruvian Corporation, which also operates the railway line from Guaqui to Alto de La Paz. The extension to Cuzco was completed only a few years ago.

The Ilo-Moquegua line was built in 1873, destroyed during the Chilean war, and rebuilt by the Government about 1908. An arrangement was recently made for its operation by the Peruvian Corporation.

The face value of the bonds, issued to cover the cost of building the lines turned over to the Peruvian Corporation in 1890, was approximately $215,000,000, gold, or over $140,000 per km. It has been estimated that the Oroya Railroad actually cost $200,000 per mile ($133,000 per km.) to build.

A message of the President to the Peruvian Congress in September, 1913, stated that the total receipts by the Peruvian Corporation from 1890 up to the end of 1912 had been as follows (taking £1 = $5):

Contract with Chile	$ 5,954,740
Guano proceeds	14 305,480
Proceeds of Rys. and steamers	21,607,950
Annual payments	2,233,330
	$44,101,500

This is less than 1% per annum on the face value of the bonds, but the original $200,000,000 were valued in 1879 at approximately only 40% of their face value, and by the end of 1889, at the time of the contract with the Peruvian Corporation, at only $15,000,000, which is probably approximately the relative value at which a large proportion of them were obtained. The annual payments are now secured by the customs receipts of Callao and are regularly met.

By 1910 a new foreign debt had been contracted as follows:

Peruvian Corporation	$10,800,000
Wharves and docks	400,000
Loan of 1905	2,500,000
" " 1906	2,000,000
	$15,700,000

Recent loans have been placed at approximately 6%. The annual revenue of the Government is from fifteen to seventeen million dollars gold.

There are a number of other roads aggregating 1074 km. as shown by the following table:

Gauge, 4′ 8½″	Length (Km.)	Date of Construction	Controlling Interest
Oroya a Cerro de Pasco	132	1904	North American
" a Gollarisquisca	43	1905	" "
Eten a Ferrenofe y Chiclayo	82	1871	Local
Lima Electric Rys.	138	1858-1907	"
Peruvian Northwestern (Ancon-Huacho-Sayan)	211	1906-1912	British
	606		
Gauge, 1 Meter			
Bayovar a Reventazon	48	1904	British
Supe a San Nicolas	6	1899	Local
Rio Pativilca a Paramonge	7	1903	"
Playa Chica a Salinas	10	1876	"
Chancay a Palpa	25	1877	"
Tambo Mora a Chincha Alta	12	1898	"
Ensenada a Pampa Blanca	20	1906	"
Santa Barbara a El Vigia	60	——	"
	188		
Gauge, 3 ft.			
Pimental a Chiclayo	24	1873	Local
Huanchaco a Tres Palos	67	1898	Italian
Chicama a Pampas	45	1898	Local
Cerro Azul a Canete	12	1870	British
	148		
Gauge, 2′ 6″			
Piura a Catacaos	11	1889	Local
Gauge, 2′ 0″			
Eten a Cayalti	36	1904	Local
Supe Barranca a Pativilca	81	1903	"
Casapalca a El Carmen	4	1901	"
	132		
Total	1074 km.		

The Cerro de Pasco Railway runs from Oroya to the famous Cerro de Pasco mines, and is owned and operated by the mining company of the same name, a North American corporation, which also operates the line to Gollarisquisca.

The Peruvian Northwestern is a group of lines to the north and west of Ancon, from which latter place they are connected with Lima by the Lima and Ancon Railway, operated by the Peruvian Corporation. They have been built mostly within the past few years.

The Lima Electric Railway consists of a group of lines between Lima, and its port Callao, Magdalena, Chorrillos and other points. Some of them have been converted from operation by steam, and the lines are partly on the old private rights of way, and others through the streets or highways.

The other lines are mostly short lines from some inland center of production to the coast, and a few of them should probably be more properly classed as industrial and mining. The general increase in total length of lines in operation is shown by the following:

The total length of the lines now in operation as of December 31, 1913, is	2914 km.
In 1908 (as given in the History of Peruvian Railways—Ministerio de Fomento)	2215 "
1898 Report of Intercontinental Ry. Commission	1472 "

The total cost of 2133 km., in 1908, was stated to be £31,081,616 or equal to about $75,000 per km.

The following shows the general increase in the traffic of the railroads (all lines):

	1888-1897	1898-1907
Passengers	22,155,802	59,700,588
Freight tons	4,153,910,152	7,683,182,281

There are several projects for extensions down the eastern slope of the Andes to the headwaters of the Amazon. From Cuzco, an extension is being built to Santa Ana, and surveys have been made from Urcos on the Cuzco line towards the Madre de Dios and the Beni Rivers. From the Cerro de Pasco Railway to the Ucayli, this latter the so-called McCune Concession, which, it is stated, carries a subsidy of about two million dollars, and a new trans-Andean line from Payta on the Pacific to the Marañon River, which it is said will cross the Andes at an elevation of less than 7000 feet. In the message of the President to Congress in 1913, the following list of new projects was stated by him to be under consideration. The

estimated cost is given in Peruvian pounds, roughly equal to $5.00 gold.

Projected Railways	Cost
Paita to the Marañon	£P 4,548,000
Railway to the Ucayli	2,000,000
Branch to the Coast	475,000
Chilete to Magdalena	150,000
Chimbote to Recuay	642,000
Vitor to Mages	81,828
Cuzco to Santa Ana	506,000
Oroya to Puerto Wertheman	3,388,200
Electric traction of same	864,800
Huancayo to Ayacucho	1,325,000
Branch to Huancavelica	202,800
Tirapata to the Madre de Dios	2,500,000
Queruvilca Railway	440,000
Sayan to Oyon and Checras	400,000
Hatunhuasi to Pachacayo	150,000
	£P17,673,628

Bolivia.

The length of operated lines and lines under construction is shown by the following table (1914):

	In Operation	Under Construction
Guaqui-Alto de La Paz	90 km.	
Arica-La Paz (Bolivian section)	233 "	
Antofogasta (Chile) & Bolivia Ry. Co.—		
Main line Chilean Border to Oruro	484 "	
Viacha-La Paz		30 km.
Bolivia Railway Co.—		
Viacha-Oruro	200 "	
Rio Mulato–Potosi	177 "	
Oruro-Cochabamba	105 "	98 km.
Uyuni-Tupiza	90 "	87 "
	1,379 "	215 "

Note.—The two last are under provisional operation only; that is, they have not been accepted formally by the Government.

All these lines are meter gauge except the Antofogasta, which is now being changed to meter.

Previously to 1903, there were only two lines in existence,

the Guaqui-La Paz and the Antofogasta to Oruro. The new lines have been built as the result of treaty arrangements with Brazil and Chile. The latter country, besides undertaking the construction of the Arica-La Paz Railway, agreed to pay the interest (not over 5%) which Bolivia might guarantee on the capital invested in the construction of certain interior lines, provided this did not exceed $500,000 in any one year, or $8,-000,000 in the aggregate. Brazil paid Bolivia $10,000,000 in cash, besides agreeing to build the Madeira & Mamoré Railway.

Guaqui-Alto de La Paz, 90 km., is operated by the Peruvian Corporation; it connects by steamer across Lake Titicaca with the line to Arequipa and Mollendo. Its net earnings are about $2000 per km.

Antofogasta (Chile) & Bolivia Railway Company, Ltd., 484 km. of main line in Bolivia, 2′ 6″ gauge, which is now being changed to meter, runs from the Port of Antofogasta in Chile to Oruro. This line has very much lighter grades (probably not exceeding 2%) than any of the other lines climbing the western slope of the Andes. The earnings of the Antofogasta lines are given under the heading of Chilean roads. It may be noted, however, that the Government of Bolivia has never been required to make any payments on account of its guarantee of 5% interest on the capital invested in this enterprise, which has been a very profitable one.

This company is a British corporation, and leases and operates the lines of the Bolivia Railway Company. The latter is a North American company, which built the main line from Viacha to Oruro in 1908-10. The branches from Rio Mulato, Oruro and Uyuni have been built since that time, under the direction of the Antofogasta Company, for account of the Bolivia Railway Company.

The Uyuni-Tupiza line is projected to eventually connect with the Argentine Government meter gauge lines at La Quiaca. Through communication, without change of cars, will then be possible between La Paz and Buenos Aires. (The section from Tupiza to La Quiaca, about 80 km. is not included in the concession to the Bolivia Railway Company, as the Argentine Government originally undertook to build this section.)

It has been stated that the total cost of the Bolivia Rail-

way from Viacha to Oruro, 200 km., was only $4.000,000 or $20,000 per km. It is to be noted, however, that although this line lies at an elevation of 12,000 feet, it follows the line of the elevated plateau parallel to the mountain ranges, and, therefore, is no criterion of the cost of other lines, especially those running east and west. The 300 km. of the Antofogasta in Bolivia is said to have cost only $3,750,000 or about $12,500 per km.

The original contract for the construction of the Bolivia Railway (Viacha to Oruro) contemplated the construction of a system of lines to cost a total amount of $27,000,000. $12,-000,000 of this was to be contributed by the Government of Bolivia and the balance by the concessionaires. The lines from Viacha to Oruro, and the branches above mentioned, have been built under this contract, the further interest in which is now in the hands of the Antofogasta and Bolivia as lessor of the Bolivia Railway. The Government guarantees 5% interest on a certain amount of bonds per mile of line built, and the deficiency on this account, for the lines of the Bolivia Railway in 1911, was about $350,000, and in 1912 about $550,000.

The Madeira-Mamoré Railway is in Brazil, and was built by that country 1909-1913 to afford an outlet from northeastern Bolivia, by furnishing means of transportation around the falls and rapids of the Madeira River, to the navigable waters of the Amazon. A further extension of 100 km., past the rapids of the Beni River, is also contemplated.

The Arica-La Paz, 1 meter gauge, 233 km. in Bolivia, was built by the Chilean Government 1911-1913, to afford an additional outlet from La Paz to the Pacific Coast. This line has 39 km. of Abt system rack with 6% gradients on the Chilean section, and normal gradients of 3%. (See also Chile.)

There are several projects for lines from the high central plateau of Bolivia, 12,000 ft. above sea level, eastward towards the headwaters of the Amazon and Paraná Rivers, and undoubtedly the future will see a great development of the rich agricultural section of Bolivia on the eastern slopes of the Andes, and rail connection easterly, via Corumbá, through Matto Grosso to Rio Janeiro, and southerly through Paraguay and Argentina to the Paraná River and Buenos Aires. It is proposed to extend the Rio Mulato-Potosi branch to Sucre and

from thence to Yacuiba or some other point on the Argentine frontier. Preliminary surveys or reconnaissances have been made for both of these lines, under concessions granted to an American corporation subsidiary to the Brazil Railway Company, the terms of which were similar to those granted to the Bolivia Railway Company.

Chile.

The total length of the railways of Chile, at the end of the year 1911, is given as 6357 km., which was about equally divided between private and Government ownership. There are eight different gauges, ranging from 2′ 0″ to 5′ 6″, the division being approximately as follows:

Narrow gauge	3,282 km.	(about 50% is less than 3 ft.)
4′ 8½″	925 "	
5′ 6″	2,150 "	
	6,357 "	

Of the privately owned lines, it is stated that 1400 km. were (in 1913) controlled by British capital, the total investment being $120,000,000.

There has been considerable activity in the development of the transportation system during the past ten years, and from 1901 to 1911 inclusive, it is stated that about $70,000,000 gold was spent in the construction of new railway lines, mostly by the Government, over half of this amount in the last three of these years; and that during the year 1910 there were 2512 km. under construction by the Government, which it was estimated would cost about $60,000,000 gold.

The main feature of the Chilean Railway system is the line running parallel to the coast, from Puerto Montt in the south to Arica in the north, traversing practically the whole length of the country, a distance of approximately 3400 km. The lower part of this line, south of Valparaiso and Santiago, is mostly of 5′ 6″ gauge, the construction of which was started in 1852, the first section being opened to traffic in 1855 from Valparaiso to Salto. The greater part of the southerly system was built previous to 1890, most of these lines forming the "Red Central del Estado", being owned and operated by the Government.

North of Valparaiso, there were a number of isolated systems, some owned by the Government, but mostly by private enterprises. In 1909-10 the construction of the so-called Longitudinal Railway was started by the Government, this being a meter gauge line, parallel to the coast, and filling the gaps between the existing lines from Valparaiso north to Arica. This has now been practically completed. It may be noted, however, that part of the existing lines north of Valparaiso are 4′ 8½″, so that through communication without change is not possible.

The following table shows the operating results of some of the principal lines for the year 1910:

(Values in Gold)

	Length Km.	Receipts Per km.	Expenses of Line	Operating Ratio
Arica to Tacna	62	4,827	2,910	60.3%
Junin	89	7,237	5,224	72.1
Caleta Buena	105	14,885	-------	------
Iquique a Pisagua	578	17,271	7,492	48.9
Antofogasta a Bolivia	821	14,332	7,711	53.8
Caleta Coloso	184	7,889	5,254	66.6
Taltal	298	12,134	7,502	61.8
Caldera	231	2,662	2,095	78.7
Carrizal	163	1,135	959	84.2
Transandino	70	13,225	10,499	79.4
Llano de Maipo	22	7,610	4,489	59.0
Curanilahue	103	14,123	7,125	50.4
Red Central del Estado	2,073	14,331	16,680	116.0

The following table shows the development of the traffic on the Government lines south of Valparaiso (Red Central del Estado):

	1900	1911
Length of line in operation, km.	1,469	2,220
Gross receipts	$14,165,972	$51,942,642
Expenditures	14,906,503	63,673,278
Number of passengers	6,565,254	11,200,984
Tons of freight	2,129,172	4,872,657

This system consists principally of a main stem, running parallel to the coast and at a comparatively short distance from it, with certain transverse lines running to ports or harbors. To some extent, it follows the more or less well defined central

valley of southern Chile, but necessarily crosses all the drainage from, and the outlying spurs of the Cordillera. The country is generally fertile, supporting a fairly numerous population, providing a good passenger traffic which naturally prefers the direct, definite service of the railroad to the more or less uncertainty and discomfort of the sea, but the freight tonnage is comparatively small. These difficulties, added to those usually incident to government ownership and operation, account for the usual annual deficit.

A study of this system is of some interest, as indicating the probable future results of operation of the Longitudinal line north of Valparaiso, which traverses more difficult and at the same time less fertile and populous sections, and is also an indication of what may be expected from the greater part of the projected Pan-American line. It is stated that the Longitudinal Railway showed an operating loss of $600,000 for the second half of 1913. It is to be noted, however, that these lines, while perhaps not warranted commercially, serve a useful and necessary purpose politically in holding or binding together the constituent states of the Federation.

The tariffs on the Chilean State Railways are shown by the following tables in Chilean currency $1.00 (one peso) being equal to 36 cts. gold.

Passenger Tariffs—Sliding Scale.

	1st Class	2nd Class	3rd Class
1 km.	$ 0.06	$ 0.04	$ 0.02
50 "	2.70	1.80	0.90
500 "	22.50	15.00	7.50
1500 "	40.50	27.00	13.50

Freight Tariffs—Sliding Scale.

Varies from 12 cts. to 2 cts. per ton per km. for 1st km. for carload lots. For less than carload lots the tariff is approximately as follows per metric quintal (200 lb.):

	1st Class	7th Class
1 km.	$ 0.01	$ 0.01
100 "	1.14	0.19
1000 "	6.00	1.00

To this is added for,

Each ticket	10 cts.
Loading per 220 lb.	5 "
Unloading per 220 lb.	5 "

The report of the Minister of Public Works shows the following results of the working of all the Government lines for the year 1912:

Length in Operation.

Red Central	2,286.4 km.
Copiapó y Chañaral	482.4 "
Huasco	49.5 "
Coquimbo	344.9 "
Los Vilos	95.0 "
	3,258.2 "

	Chilean Currency
Total receipts	$65,349,941
" expenses	75,511,340
Estimated cost of lines	428,837,703
Cash and material on hand	48,706,510
Accumulated losses on operation	87,344,227

Of the other lines, the most important (with the two exceptions noted below) are generally groups, which have been developed from the numerous ports, reaching inland to important nitrate deposits or mining districts.

The Antofogasta (Chile) and Bolivia Railway should, in a sense, be included in the above mentioned grouping, as much of its business is the haulage of nitrate to the port of Antofogasta; but its character is also international as it reaches into Bolivia, having provided for a long time, one of the only two outlets to the Pacific Coast and exterior world from that country, and has handled the products of the most extensively worked of the Bolivian mines. This railway is unique among the railways climbing the South American cordillera, inasmuch as it reaches an elevation of 12,000 ft. with an average rate of gradient of a little over 1%, a maximum of about 2%, and little if any development or lost distance. It has been one of the most profitable lines in South America. (See also Bolivia.) The following figures are from the Annual Report of the Company (British) for the year ending June 30, 1914, at which time the total length operated was 1284 km. (in both Bolivia and Chile and for the railroad only and taking £1 = $5).

	1904	1913
Gross receipts	$3,122,365	$9,058,870
Working expenses	1,566,745	5,196,895
Net receipts	$1,555,620	$3,861,975
Number of passengers	149,870	609,713
Tons of nitrate	38,294	848,577
" " other freight	478,801	1,018,205

The Transandino. This forms the connecting link on the Chilean side between the Chilean railways and those of the Argentine. It is part of the through railway line from Buenos Aires, Argentine to Valparaiso, and the only transcontinental line in South America. It is meter gauge from Los Andes in Chile to Mendoza in the Argentine, a distance of 250 km., and connects at both ends with the 5′ 6″ gauge lines of both the Argentine and Chile. It was completed in 1910.

The summit tunnel is 10,500 ft. above the sea level. The adhesion gradients are 2% on the Argentine side and 2½% on the Chilean side, with rack gradients of 8%. There has been considerable trouble from snow and earth slides during the winter months, especially on the Chilean side.

Other Transandine lines. There will probably be completed before many years a connection between the lines of the Buenos Aires Great Southern, Neuquen extension and the lines in southern Chile near Victoria, both of which are of the same gauge (5′ 6″).

Other connections in the north have been proposed, but there seems little likelihood of their construction in the immediate future. There has been some talk of changing the present transandine to 5′ 6″ gauge, but this is hardly probable for at least some time to come.

The Arica-La Paz Railway was built between 1909 and 1913 by the Chilean Government, in compliance with the terms of a treaty with Bolivia. It is 439 km. in length, of which 206 km. are in Chile. It has 3% adhesion gradients and a rack section of 40 km. of 6%. It is operated throughout its length by the Chilean Government.

Argentine.

The Argentine has the most important railway development of any of the South American countries, as will be seen by the statistical tables which follow. The principal development has been of the territory immediately tributary to the capital, Buenos Aires, and secondarily of that, tributary to the cities of Bahia Blanca and Rosario. The past twenty-five years have been a period of transition from an almost entirely pastoral country to an agricultural one, the former industry being now pushed farther afield, and followed rapidly by increasing development of territory devoted to the production of cereals, etc. As in the United States, this development has followed the railways and has been along very similar lines, aided largely by European emigration. Most of the railway development, in the section above referred to, has been by British interests, comprising most of the lines of 5′ 6″ gauge. There are three gauges, 5′ 6″, 4′ 8½″, and meter, the length of each in kilometers being as follows on December 31, 1912:

	Operated	Provisional*	Total
5′ 6″	19,164 km.	740 km.	19,904 km.
4′ 8½″	2,518 "	131 "	2,649 "
Meter	9,283 "	1,018 "	10,301 "
			32,854† "

The railways are owned mostly by foreign corporations. There is one local company, and the rest are owned and operated by the Government, the distribution being as follows:

	Length	Capital invested
British	22,908 km.	$ 875,000,000
French	3,770 "	112,000,000
Argentine Private	269 "	9,000,000
Argentine Government	5,907 "	122,000,000
	32,854 "	$1,118,000,000

* Provisional. Operated, but not formally recognized by the Government.

† The length for 1913 is given as 33,478 km. (probably not including provisionally operated lines).

The details of each line are shown in Table 7 for the year 1912.

The lines operated by the Government have been built to expedite and aid in the development of the outlying provinces, and to link them and their capitals together and with the Federal district. As these lines prove remunerative, it has been, and probably will continue to be the policy of the government to sell or lease them to private enterprises, and use the money for further development elsewhere.

The Federal Government exercises quite close control over the construction and operation of all the lines, this control and regulation being based to quite a considerable extent on French practice, although the principal development has been by British capital, and under the direction of British engineers and operating officials, which, of course, has had its influence. Much of the equipment of the Government lines has, however, been obtained from the United States, and the operating officials seem to be inclined to favor United States practice. The operation of the Government lines is by an organization separate from that which has general control of the railways as a whole. There is also provincial control of lines which lie entirely within the boundaries of any one province, though lines once passing a provincial boundary must conform in every respect to the Federal regulations.

In the section south of Santa Fe, Cordoba and San Juan, as far as Bahia Blanca, future development will generally be by extension of existing systems. Towards the north, there will be new trunk lines built, through the so-called Chaco up into Bolivia. Much of this country will undoubtedly be comparatively rapidly developed for agricultural and pastoral purposes. The provinces of Entre Rios and Corrientes, previously isolated, were linked up with Buenos Aires on the south in 1908, and Paraguay on the north in 1913, by means of car-ferries across the Parana River, so that through trains are now operated between Buenos Aires and Asuncion. The extension of the railway system to the southwest from Bahia Blanca is not proceeding as rapidly, perhaps, as in other parts of the republic, but equally surely, and the completion of a second transcontinental line (5′ 6″ gauge) from Bahia Blanca, via Neuquen,

to connect with the broad gauge lines of southern Chile, is probably a matter of only a comparatively short time. The development of the southern section of the Argentine towards Patagonia, which was formerly considered to be, like most of the Canadian Northwest, a barren waste, is likely to afford a close parallel to the development of the latter.

The only transcontinental line in South America at present runs from Buenos Aires, via Mendoza, to Valparaiso, Chile. The trans-Andean section, which is the part crossing the Andes, is 1 m. gauge, and connects with 5′ 6″ gauge lines at both sides, so that two changes of trains are necessary in order to make the complete trip. The service has generally been interrupted by snow and slides during the winter months, but this difficulty will probably be overcome in the future. With the closing of the short gap in Bolivia between La Quiaca and Tupiza, through rail communication will be possible between Buenos Aires and Antofogasta in Chile or Mollendo in Peru.

In view of the somewhat prevalent idea that the railways of South America are usually built and operated on a much lower standard than those of Europe and the United States, it seems desirable to point out the fact that both in construction, equipment and service, the main lines in the Argentine compare favorably with any elsewhere, though in the, as yet, undeveloped sections of the country, the policy adopted in the United States of building comparatively cheap lines, and afterwards improving them, has been generally followed.

The adoption of the 5′ 6″ gauge for the principal lines of the Argentine has brought about the usual result, the adoption of the narrow gauge for cheaper lines, which is particularly unfortunate in a country where the cost of the construction of the roadbed is usually quite low. The standard gauge (4′ 8½″) is practically confined to the provinces of Entre Rios and Corrientes. There is no fuel (except wood in some sections of the north) produced in the Argentine, so that all the coal used has to be brought from Europe or the United States. A small amount of fuel oil is produced in the extreme south. Wages are fairly high, and the men are affiliated with labor unions, which have a not inconsiderable voice in politics. The structures of the main lines are usually of masonry and steel, as tim-

ber is scarce and expensive; 100 lb. rails, hardwood ties, and stone ballast are used on the principal lines. The equipment is generally of the American type, rather than European. Train control is by the Via Libre (Clear Line) system, with semaphore signals at way stations, operated by the agents. In the vicinity of the larger terminals, the block system is used. The English staff system is used on some lines of heavy traffic. There are about 1000 km. of double track.

The general progress of railway construction as shown in Table 5 has been quite steady and rapid since 1880, except for the setback for the two or three years following the panic of 1890. The Balkan War of 1912 resulted in a general slowing up in the Argentine as elsewhere, and, of course, the present European War has brought everything almost to a standstill, the earnings for the year ending June 30, 1914, being some $15,000,000 behind the previous year, and practically all new construction has been suspended.

The statistics shown in Tables 8, 9 and 10 are from the official Government report covering the year ending December 31, 1909, and Table 6 shows the progress from 1909 to 1913, which was about normal up to that time, but has decreased since then for the causes stated above.

Uruguay.

The most important system in Uruguay is that of the Central Railway of Uruguay, running northerly from Montevideo and spreading out fan shape to practically all sections of the Republic. All the railways are 4′ 8½″ gauge. They have been built and are operated almost entirely by British interests, closely allied with those which control the principal railways of the Argentine.

In recent years, the Government has endeavored to interest capital in another network of lines to cover the country in the spaces not now occupied by the lines of the Central. It is proposed to guarantee the interest on bonds to the amount of about $25,000 per km. (to be issued at about 90), and provisional negotiations have been concluded, which however, await the ratification of Congress. It is also proposed that some of these lines shall be built by, or wholly for account of, the Government.

The Central Railway of Uruguay, with its extensions and branches, has a length of about 1570 km. Its earnings for 1912-13 were approximately

Gross	$6,216,960
Net	3,134,295

The construction of this system was started in 1866, and about two years ago connection was made at Rivera—Santa Ana with the lines of the Brazil Railway Company (meter gauge), which permits through connection, with two changes of gauge between Montevideo and Rio de Janeiro.

The Midland, Northern and Northwestern, are short lines in the northwestern section of the Republic, respectively 470, 114 and 182 km. in length. They have gross receipts of about $1,200,000, and operating expenses about $800,000.

The Uruguay East Coast Railway is a short line, 126 km., running easterly from Montevideo (Olmos) to San Carlos. Working results, 1911-12,

Gross	$176,607
Expenses	143,443
Net	$ 33,164

This line works under Government guarantee and it is proposed to extend it to Rocha.

Rocha-Palomas, 30 km., built 1913-14 from Rocha to the Port of Palomas. It is proposed to extend this line easterly to the Brazilian border at Artigas.

There is a project for a line from Montevideo to Colonia, a point on the coast directly opposite and only about 25 miles from Buenos Aires, with which it is proposed to establish direct connection by high speed ferries, shortening the time between the two capitals to 4 or 5 hours, and permitting, eventually, through rail connection, without break of gauge from Buenos Aires to Rio.

Paraguay.

The Paraguay Central Railway is the only line in Paraguay and runs from Asuncion, the capital, to Encarnacion on the Paraná River, where it connects by car ferry with the lines of

the North East Argentine Railway and so through to Buenos Aires. Its length is 374 km., gauge 4′ 8½″.

A branch line has been started from Villa Rica, running easterly toward the mouth of the Iguazu River, which it is intended will eventually form part of a through line to Sao Paulo and Rio in Brazil.

The northerly section of the Paraguay Central, from Asuncion to Villa Rica, was built some 60 or 70 years ago and was of 5′ 6″ gauge. It was changed to 4′ 8½″ and extended to the Argentine border (Encarnacion) about four or five years ago, the Argentine Government granting a subsidy for this purpose and to cover the cost of new rolling stock. (The gauge of the Argentine lines with which it connects in Corrientes and Entre Rios is 4′ 8½″.) The road was partly destroyed and traffic suspended during the revolution in the early part of 1912. Through communication with Buenos Aires was established at the end of the year 1913.

The revenues for the year ending June 30, 1913, are given as follows:

Gross	$732,557
Expenses	$402,871
Net	$329,686
Ton miles per mile of line	59,678
Pass. miles per mile of line	46,172

Brazil.

Brazil has an important system of railways, but it has been found difficult to obtain reliable and complete data in regard to its present status.

The first railway line was built in 1854, but there was no very rapid progress until after the establishment of the Republic in 1889, which resulted in the autonomy of the various states and greater liberality in the laws governing the granting of concessions.

The following table shows the progress of construction:

1854	14	km.
1890	9,648	"
1900	14,648	"
1906	17,340	"
1913	22,287	"

Many lines were built under guarantees of interest, but the burden of this finally became so great that many of the lines were purchased by the Governments, both State and Federal, and leased to operating companies. The distribution between Government and private ownership at the end of 1913 was stated to be as follows:

Kilometers	In Operation	Under Construction	Surveyed
Federal lines worked by the Union	3,344	435	435
Federal lines leased and controlled by Union	7,462	2,083	2,882
Lines built under concessions granted by Union with guarantees of interest	3,147	256	837
Lines built under concessions granted by Union without guarantees of interest	1,934	189	1,260
Lines belonging to or conceded by separate States of the Union	6,400	865	259
	22,287	3,828	5,673

Most of the lines are meter gauge, the exceptions being the following:

Central of Brazil	1,032 km.	5′ 3″
Sao Paulo (part)	139 "	5′ 3″
Paulista (part)	281 "	5′ 3″
Recife-Caxanga	25 "	4′ 0″
Recife-Olinda	12 "	4′ 8½″
Sao Paulo & Minas	138 "	2′ 0″
Mogyana (part)	78 "	2′ 0″
Paulista (part)	51 "	2′ 0″

The following statistics will give some further idea of the extent and traffic of the railways for the period 1897-1905, though it is to be noted that this only covers about 65% of the total length operated.

	1897	1901	1905
Length operated km.	8,581	9,287	11,113
Gross receipts gold	$22,862,700	39,925,930	29,851,392
Expenditures "	23,629,170	23,362,025	22,224,270
Net "	5,233,530	9,563,905	7,637,122
Number of passengers	----------	468,203,518	621,135,840
Tons of freight	----------	588,084,087	619,204,687

The following statement shows the total receipts and expenses (gold) of all the lines for the year 1910, divided between those owned by the Government and owned privately.

	Lines Owned by Government	Lines Owned by Private Corporations
Total receipts	$21,174,239	$15,995,118
" expenses	20,709,694	11,322,766
Net earnings	$ 464,545	$ 4,672,352

The railways of Brazil were, on the whole, fairly prosperous up to about the year 1912. At that time, the decline in the value of coffee, which the project for valorization was not able to sustain, and a similar but more acute decline in the value of crude rubber, due to the competition of plantation rubber, produced a depression which the Balkan War, and finally the great European War, developed into a financial crisis. For the present, therefore, railway affairs are at a low ebb, and the development of the agricultural states of the south, and the extension of lines westerly across the valley of the Paraná towards Bolivia, which was proceeding with some vigor, has been temporarily suspended.

Future developments will be in the development of the states to the south of Sao Paulo by branches and extensions of existing lines, with eventually a connection with Paraguay, via the valley of the Iguazu. North and west of Sao Paulo and Rio, transcontinental lines will eventually be pushed across the River Paraná, and across the states of Matto Grosso and Goyaz. Much of this country is open pasture at elevations of 2000 to 5000 ft. above sea level, with an agreeable climate, and not tropical jungle as is quite generally supposed. The line across the lower end of the state of Matto Grosso, from Itapura in Sao Paulo towards Corumbá, is getting well along towards completion, and it seems probable that this will eventually be extended to Sucre, and so connect with the railway system of Bolivia. All the groups north and east of Rio will, of course, gradually extend their systems from the coast back into the country as such developments are warranted, and it is planned to extend the government lines northerly to Para on the Amazon.

The **Brazil Railway Company**, a North American corpora-

tion, which also has large interests in the Mogyana and Paulista companies, has operated since 1908 all the lines in the southern part of Brazil, south of Sao Paulo; the total length of the lines thus controlled being as follows (June 30, 1913):

Brazil Railway Company	5,282 km.
Paulista	1,160 "
Mogyana	1,728 "
	8,170 "

The lines controlled by the Brazil Railway Company were originally operated independently by several different companies. After the consolidation, new lines were built to link up the various component parts, and at the southern end, connection has been made with the lines of Uruguay (4′ 8½″ gauge), thus permitting through rail connection from Montevideo to Rio (though with two changes of gauge). The earnings of the Brazil Railway Company have been approximately as follows:

	Gross	Net
1908	$ 7,844,345	$3,361,990
1909	9,177,110	4,547,815
1910	10,192,455	4,481,145
1911	11,672,760	5,140,850
1912	13,057,690	5,573,795
1913	14,479,919	5,279,385

(Values in gold.)

The Paulista and Mogyana systems are owned principally by the Government. The first was built almost entirely with Brazilian capital, and the latter under both State and Federal guarantees. They are both prosperous as shown by the following statements of earnings:

The Paulista.

	Length Operated km.	Gross Receipts Gold	Operating Ratio
1908	-------	$ 7,082,650	46 %
1909	-------	8,472,450	46 "
1910	-------	7,210,000	45 "
1911	1150	8,942,400	42 "
1912	1150	10,319,146	46.4 "
1913	1160	11,348,500	52.4 "

The Mogyana.

	Length Operated km.	Gross Receipts Gold	Operating Ratio
1908	-------	$ 5,750,850	53.8 %
1909	-------	6,401,250	52.0 "
1910	-------	5,693,750	61.2 "
1911	1513	6,935,700	57.2 "
1912	1604	8,130,380	54.4 "
1913	1728	8,694,380	61.9 "

The Madeira-Mamoré Railroad was built for the Brazilian Government by the Brazil Railway Company, which also operates it under lease. Its length is 364 km., and it was opened for operation in September, 1912. The traffic receipts for 1913 were about $1,700,000.

The line was built by Brazil in compliance with the terms of a treaty with Bolivia, its purpose being to provide transportation from the navigable waters of the River Mamoré in Bolivia, around the falls and rapids, to the navigable waters of the Madeira. The treaty also provides for the construction of a branch 100 km. in length from the westerly end of the Madeira and Mamoré Railway along the River Beni.

The Central Railway of Brazil (originally the Dom Pedro II Railway) is one of the most important systems. It branches out fan like from Rio, one main line running to Sao Paulo. It is owned and operated by the Government. Its length at the end of 1913 was 1968 km., partly 5′ 3″ gauge, partly meter, partly mixed. In 1905 its length was 1617 km., and the gross receipts about $9,500,000 gold, with expenses of almost the same amount.

The Leopoldina system is a network of lines lying to the north and east of Rio. It is owned and operated by a British corporation. Its length in 1913 was 2820 km., and the results of operation were as follows:

Gross receipts	$3,171	per km.
Expenses	2,040	" "
Net receipts	1,131	" "

The Sao Paulo Railway is one of the most profitable lines in Brazil. It is owned by British interests, and is a short line

with 139 km. of 5′ 3″ gauge and a feeder of about 80 km., meter gauge. It has 10 km. of inclines with 8% gradients operated by cables. Its total receipts in 1905 were about $7,000,000, with expenditures of just about 50% of that. The results of operation for the first six months of 1913 were as follows:

Gross receipts	$4,972,105
Expenses	3,989,385
Net receipts	982,720

The Great Western Railway of Brazil operates a group of lines running inland from Pernambuco (Recife) and also northerly and southerly, parallel to the coast. The total length operated in 1913 was 1625 km. The lines are owned by the Government and operated by British interests, closely allied with those controlling the larger railway systems of the Argentine. For the year ending December 31, 1912, with a length of 1620 km., the results of operation were as follows:

Gross receipts	$3,424,925
Expenses	2,279,690
Net receipts	1,145,235

APPENDIX.

TABLE NO. 1.

Country	Length of Railways—Kilometers Narrow	Gauge 4′ 8½″	Broad	Total	Area Sq. Miles	Population	Sq. Miles per Km. of Line	Population per Km. of Line
North America								
Canada	11,200	446,872		50,342	3,745,574	6,000,000	74	119
United States				407,730	2,973,890	98,000,000	7.3	240
Alaska	268	482		750	586,400	75,000	782	100
Newfoundland	1,162			1,162	40,200	250,000	34	215
Mexico*	1,931	17,381		19,312*	767,005	13,607,260	40	704
Central America								
Guatemala	762			762	48,250	1,842,134	63	2,417
Salvador	248			248	7,225	1,116,253	29	4,501
Honduras	304	94		398	46,500	500,136	117	1,275
" (Brit.)	40			40	7,562	41,000	189	1,025
Nicaragua	278			278	49,200	550,000	177	1,978
Costa Rica	687			687	18,500	331,340	27	482
Panama			100	100	32,000	361,000	320	3,610
West Indies								
Cuba	315	3,410	73	3,798	41,634	2,048,980	11	539
Jamaica		320		320	4,207	806,690	13	2,521
Porto Rico	437			437	3,345	1,118,012	7.6	2,327
Hayti	383			383	28,000	1,500,000	73	3,916
San Domingo	237			237	18,045	500,000	7.6	2,110
Barbados	42			42	166	200,000	4	5,000
Trinidad		191		191	1,754	55,000	9	288

South America								
Dutch Guiana	173			173	57,900	84,103	34	486
British Guiana	53	97		150		301,923		2,013
Venezuela	947			947	600,000	2,663,671	634	2,813
Colombia	1,065			1,065	481,980	4,279,674	453	4,019
Ecuador	464			464	60,000	1,500,000	130	3,233
Peru	656	2,269		2,925	676,638	3,547,829	231	1,213
Bolivia	1,379			1,379	700,000	1,816,271	508	1,317
Chile	5,026	862	829	6,717	307,774	1,381,317	46	206
Argentine	10,301	2,649	19,904	32,854	1,083,596	5,410,028	33	165
Uruguay		2,462		2,462	72,210	1,042,668	29	424
Paraguay		374		374	97,700	631,347	261	1,688
Brazil	20,823	12	1,452	22,287	3,270,000	17,318,556	147	777
	59,181	477,475	22,358	559,014				

Note.—Narrow Gauge 2′ 0″ to 3′ 6″
Broad " 5′ 3″ and 5′ 6″

With very few exceptions the above data are as nearly as possible correct for the year ending Dec. 31, 1913, or June 30, 1914. The exceptions are thought to be not important.

* Mexico. According to the President's message of April, 1909, there were 14,857 miles in operation, of which 11,851 miles were operated by the Government. The figures given above were taken from Poor's Manual for 1914, in which there may be some omissions—but these latter may be only industrial lines.

TABLE NO. 2.

Canadian Railways—Statistics.

Passenger	1907	1908	1909	1910	1911	1912	1913
Miles of railway	22,452	22,966	24,104	24,731	25,400	26,727	29,336
Number of passengers	32,137,319	34,044,992	32,683,309	35,894,575	37,097,718	41,124,718	46,230,765
Passengers carried one mile	2,049,549,813	2,081,960,864	2,033,001,225	2,466,729,664	2,605,968,924	2,910,251,636	3,265,656,080
Passengers one mile per mile of line	90,921	90,654	84,342	99,742	102,597	108,888	111,353
Passengers per mile of line	1,431	1,482	1,355	1,451	1,460	1,539	1,576
Average passenger journey (miles)	64	61	62	69	70	71	71
Avg. number of passengers per train	56	54	51	59	60	62	62
Passenger train mileage	30,220,461	31,950,349	32,295,730	35,022,541	36,985,911	40,440,393	45,652,365
Mixed train mileage	5,971,414	6,210,807	7,061,580	6,441,440	6,277,468	6,473,882	7,044,194
Earnings from ticket sales	$39,184,437	$39,992,503	$39,073,488	$46,018,880	$50,566,894	$56,543,664	$64,441,430
Earnings from passenger service	$45,730,652	$46,854,158	$45,282,326	$52,956,219	$58,317,998	$65,048,187	$74,431,994
Average receipts per passenger	$1.219	$1.174	$1.195	$1.282	$1.360	$1.375	$1.394
Avg. recpts. per pass. per mi. (cts.)	1.911	1.920	1.921	1.866	1.944	1.943	1.973

Freight							
Tons hauled	63,866,135	63,071,167	66,842,258	74,482,866	79,884,282	89,444,331	106,992,710
Tons hauled one mile	11,687,711,830	12,961,512,519	13,160,567,550	15,712,127,701	16,048,478,295	19,558,190,527	23,032,951,596
Tons hauled one mi. per mi. of line	518,486	564,378	545,991	635,321	631,829	731,776	785,820
Average haul, miles	183	206	197	211	200	218	216
Freight train mileage	38,923,890	40,476,370	40,304,906	50,184,108	52,498,866	60,126,023	67,320,090
Mixed train mileage	5,971,414	6,210,807	7,061,580	6,441,440	6,277,468	6,473,882	7,044,194
Revenue from freight	$94,995,087	$93,746,655	$95,714,783	$116,229,894	$124,743,015	$148,030,269	$174,684,640
Average tons per train	260	278	278	311	305	325	342
Average cars per train	16.92	16.04	16.37	18.15	18.03	18.19	18.00
Average tons per car	15.37	17.33	16.98	17.13	16.91	17.87	19.01
Avg. recpts. per ton per mile (cts.)	.815	.723	.727	.739	.777	.757	.758
Earnings, Etc.							
Passenger train mile	$ 1.263	$ 1.228	$ 1.150	$ 1.277	$ 1.348	$ 1.390	$ 1.412
Freight " "	$ 2.069	$ 2.008	$ 2.041	$ 2.316	$ 2.376	$ 2.494	$ 2.595
Per mile of line	$6,535	$6,397	$6,018	$7,034	$7,430	$8,209	$8,750
Expenses " "	$4,620	$4,673	$4,340	$4,869	$5,159	$5,639	$6,204
Net earning "	$1,915	$1,724	$1,678	$2,165	$2,271	$2,570	$2,546
Earnings per train mile	$ 1.95	$ 1.87	$ 1.82	$ 2.04	$ 2.10	$ 2.17	$ 2.26
Expenses " " "	$ 1.38	$ 1.36	$ 1.31	$ 1.41	$ 1.46	$ 1.49	$ 1.60

TABLE NO. 3.

Canadian Railways—Statistics.

Year	Mileage Main Line‡	All in Millions						Ratio %
		Capital-ization	Cash Subsidies†	No. of Passengers Carried	Tons 2,000 lb. Freight	Earnings	Operating Expenses	
1876	5,218	$ 257	$ 28	5.54	6.33	$ 19.4	$ 15.8	81.8
1880	7,194	271	59	6.46	9.94	23.6	16.8	71.0
1890	13,151	605	131	12.82	20.79	46.8	32.9	70.2
1900	17,657	784	155	21.50	35.95	70.7	47.7	67.4
1910	24,731	1,410	201	35.89	74.48	174.0	120.4	69.2
1913	*29,304	1,531	218	46.23	106.99	256.7	182.0	70.9

‡ First line built in 1836; the 1,000 mile mark reached in 1855.

* Additional track in main line and sidings in 1913, 8,919 miles.

† In addition to land grants and guarantees. See pg. 55.

Division of Traffic—1913.

	Tons	%
Products of Agriculture	17,196,802	16.31
" " Animals	3,173,562	3.01
" " Mines	40,230,542	38.16
" " Forests	16,609,100	15.75
Manufactures	19,694,240	18.68
Merchandise	4,365,852	4.14
Miscellaneous	4,161,154	3.95

The principal increases during the past 7 years are in Mines and Manufactures and decrease in Forest Products.

Division of Operating Expenses—1913

		%
Way and Structures	$35,933,322	19.74
Equipment	37,289,718	20.48
Traffic	6,143,201	3.37
Transportation	96,688,264	53.12
General	5,957,184	3.29

	Per Mile of Line	
	1907	1913
Maintenance of Way	$930	$1,225
" " Equipment	965	1,271

	Equipment	
	1907	1913
Locomotives	3,504	5,119
Passenger Cars	3,642	5,696
Freight "	107,407	182,221
Service "	....	15,526
Av. capacity of Freight Cars, tons	27	32

TABLE NO. 4.

Comparative Statistics of the Railways of the United States.*

To June 30th	1902	1912
Miles of line	200,155	249,852
" " main line track	215,974	279,219
" " all track	274,195	371,238
Total capital securities**	$12,134,182,964	$19,752,536,264
Dividends—Per cent of stock paying dividends	55.4%	64.7%
Average rate on above	5.55%	7.17%
" " " all stock	3.08%	4.64%
Total operating revenues	$ 1,726,380,267	$ 2,842,695,382
" " expenses	$ 1,116,248,747	$ 1,972,415,776
Net " revenue	$ 610,131,520	$ 870,279,606
Operating ratio	64.6	69.3
Number of employees	1,189,315	1,716,380
Average daily compensation of employees	1.92	2.42
Number of locomotives	41,225	62,262
" " passenger cars	36,987	51,490
" " freight cars	1,546,101	2,215,549
Average tractive force per locomotive, lbs.	20,485	28,634
Average capacity of freight cars, tons	28	37
Passengers carried one mile	19,689,937,620	33,132,354,783
" miles per mile of line	99,314	136,699
" average journey miles	30	33
" average receipts per passenger mile, cts.	1.986	1.987
Freight, total tons	581,832,441	998,282,525
" tons one mile (millions)	157,289	264,081
" " miles per mile of line	793,351	1,078,580
" average haul, miles	239	257
" " receipts per ton mile, cts.	.757	.744

* Bureau of Railway Economics.

** About 60% of this is Funded Debt.

Argentine Railways.

TABLE NO. 5.

Year	Lengths Km.	Dollars, Gold Capital	Gross Earnings
1860	39	741,000	98,320
1870	732	18,835,000	2,502,000
1880	2,516	62,964,000	6,560,000
1890	9,432	321,264,000	26,049,000
1900	16,563	530,820,000	41,401,000
1910	27,713	1,099,700,353	111,448,555
1913	33,478	1,358,849,967	140,802,754

TABLE NO. 6.

	1909	1913
Length of line in operation	25,457	33,478
Capitalization	1,018,609,000	1,358,850,000
Gross receipts	103,198,000	140,803,000
Expenses	61,197,000	88,078,000
Net earnings	42,001,000	52,724,000
Total passengers	51,065,000	82,630,000
" tons freight	31,200,000	42,917,000

TABLE NO. 7.

Argentine Railways.

	Length Km.	Capitalization	Earnings, Gold Gross	Earnings, Gold Net	Per Cent
Broad Gauge					
Southern	5,608	$220,503,600	$27,127,561	$11,311,439	5.12
Western	2,669	101,959,200	12,225,441	5,474,275	5.36
Pacific	5,342	216,086,900	24,405,713	9,185,113	4.25
Central Argentine	4,751	197,276,600	26,360,600	11,481,579	5.82
Rosario Puerto Belgrano	794	30,957,100	553,575	903,958	......
Total	19,164	$766,783,400	$90,672,295	$38,356,364	5.00
Medium Gauge					
Entre Rios	1,175	$30,391,700	$2,379,390	$ 908,096	2.98
Northeast Argentine	1,074	29,538,100	1,609,335	622,090	2.10
Central of Buenos Aires	269	8,942,800	977,091	305,389	3.41
Total	2,518	$68,872,600	$4,965,816	$1,835,575	2.68
Narrow Gauge					
Government lines	4,018	$121,872,900	$6,292,069	$359,428	0.43
Central Cordoba	1,935	70,525,000	8,220,351	2,253,352	3.19
Santa Fe	1,709	42,131,700	5,787,433	2,085,278	4.95
Province of Buenos Aires	1,367	39,399,300	2,497,010	527,847	1.34
Transandine	185	8,902,800	676,605	125,299	1.76
Central del Chubut	86	1,255,200	177,326	83,989	6.69
Tranvia a Vapor de Rafaela	83	467,100	44,891	12,976	......
Total	9,283	$284,554,000	$23,695,658	$5,454,217	1.95

TABLE NO. 8.

Argentine Railways—Rolling Stock, December 31, 1909.

	Locomotives			Freight Cars		
	No.	Average Weight with Tender	Pass. Cars, No. of	Total No. of Cars	No. of Cars per Km. Line	Capacity in Tons per Km. Line
Broad Gauge						
Southern	546	81.3	578	12,330	27.9	583.8
Western	292	82.6	263	6,806	31.9	889.8
Pacific	646	92.6	338	10,748	28.8	661.5
Central Argentine	544	77.3	514	14,899	38.1	752.2
Medium Gauge						
Entre Rios	51	68.3	47	983	10.0	249.6
Northeast Argentine	49	48.1	53	693	8.4	106.9
Central of Buenos Aires	32	36.6	20	719	27.7	201.3
Narrow Gauge						
Government lines	241	59.1	180	3,814	11.4	255.9
Central Cordoba	164	61.6	161	3,808	29.0	434.5
Santa Fe	121	48.8	126	4,021	23.0	332.2
Province of Buenos Aires	71	68.0	94	1,611	26.8	670.5
Transandine	23	43.9	20	184	10.5	101.4

TABLE NO. 9.

Argentine Railways—Traffic Statistics, 1909.

	Passengers			Freight			
	No. per Km. of Line	Average Length of Journey, Km.	Receipts per Pass. Km. Cts.	Tons per Km. of Line	Ton Km. per Km. of Line	Average Haul, Km.	Receipts per Ton Km., Cts.
Broad Gauge							
Southern	131,270	33	1.23	1,539	271,485	176	2.03
Western	113,431	35	1.22	1,579	331,435	210	2.34
Pacific	69,810	39	1.33	1,270	259,461	206	2.70
Central Argentine	140,075	39	1.23	1,772	366,421	207	2.26
Medium Gauge							
Entre Rios	26,507	88	1.62	637	101,971	160	2.15
Northeast Argentine	17,140	102	2.12	324	75,808	234	3.03
Central of Buenos Aires	183,963	170	0.40	1,176	199,948	170	1.81
Narrow Gauge							
Government lines	14,304	44	1.82	510	74,814	138	1.75
Central Cordoba	56,690	70	1.17	2,545	404,506	163	1.48
Santa Fe	20,109	46	2.07	1,068	243,492	228	2.45
Province of Buenos Aires	27,228	49	1.31	1,263	231,153	183	1.62
Transandine	24,449	14	5.08	187	28,262	151	4.47
Average of all lines	82,494	39	1.23	1,279	249,622	195	2.24

TABLE NO. 10.

Argentine Railways—Receipts and Expenditures, 1909, per Kilometer of Line.

	Receipts					Expenses					
	Passenger	Express	Freight	Miscell-aneous	Total	Mtce. of way	Traction and movement	Traffic	Direction	Total	Net Earnings
Broad Gauge											
Southern	$1,620	$400	$3,126	$173	$5,219	$516	$1,398	$543	$281	$2,738	$2,481
Western	1,380	265	3,694	190	5,529	695	1,412	600	347	3,054	2,475
Pacific	871	129	3,504	70	4,574	350	1,714	466	314	2,844	1,730
Central Argentine	1,727	181	4,007	152	6,067	594	1,663	743	416	3,416	2,651
Medium Gauge											
Entre Rios	430	46	1,371	42	1,889	246	419	179	143	987	902
Northeast Argentine	363	16	984	24	1,387	200	391	93	110	794	593
Central of Buenos Aires	727	90	2,124	76	3,017	346	931	567	173	2,017	1,000
Narrow Gauge											
Government lines	263	13	952	27	1,255	257	618	142	85	1,102	153
Central Cordoba	643	37	3,664	298	4,642	477	1,287	523	308	2,595	2,047
Santa Fe	416	48	2,618	36	3,118	560	867	370	226	2,023	1,095
Province of Buenos Aires	357	61	2,046	110	2,574	396	961	712	129	2,198	376
Transandine	1,242	43	837	52	2,174	559	1,521	157	102	2,339	*165
Average of all lines	$1,016	$144	$2,862	$117	$4,139	$458	$1,247	$467	$268	$2,440	$1,699

* Loss.

Paper No. 73

ITALIAN RAILWAYS.

RESULTS OF TEN YEARS OF STATE MANAGEMENT.

By

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GENERAL INFORMATION.

The railways of Italy (Fig. 1) can be divided into two systems: Principal Lines, owned and worked by the State, and measuring a total of about 13,500 kilometers (8,400 miles); and Secondary Lines, owned and worked by many independent private companies, measuring about 6,000 kilometers (3,700 miles). The latter act as feeders for the principal lines and are of great benefit to the public, as they reach places in the mountains where, the traffic being very small, an ordinary line could not run at a profit.

Except on some mountain lines which are of narrow gauge, Italian railways are of the "normal gauge", of 1.445 meters (4 ft. 8½ in.), adopted all over Europe, except only in Spain and Russia.

Italy being a country generally hilly, and in some parts quite mountainous, railways are costly to construct—as tunnels, viaducts and important bridges are very numerous: they are also very costly to work, owing to heavy gradients—up to 1 in 40 and in a few cases even 1 in 28—and to the fact that all the coal is imported, mainly from England and in smaller quantities from Germany and America. Thus the average working expenses in 1913 on the State Lines were 36,650 francs per kilometer ($11,200 per mile).

Map Showing Italian State Railway.

On the other hand, the revenue is rather low, as in Italy there are no great mines nor forests, and the goods traffic consists principally of agricultural products, which, in general, cannot afford a high tariff. The passenger rates also are very moderate. Thus, in 1913-14 (see Appendix) the revenue on the State Railways was 44,950 francs per kilometer ($13,750 per mile), which makes the "coefficient of exploitation" (operating ratio) 81.5% of the revenue.

Traffic Conditions.

To understand this "coefficient" and compare it with other lines, it is necessary to know under what condition Italian State Railways are worked and the class of traffic they carry.

First of all, tariffs are rather low—the law requires that for the first-class tickets the rate shall not exceed 2 cents per kilometer (about 3 cents per mile); for second-class, 1½ cents; and for the third-class, 1 cent. On a few lines there is even a fourth-class, at the rate of ¾ cent per kilometer. And these rather trying conditions are aggravated by another law, which requires that on all lines, regardless of the extent of the traffic, three couples of trains, at the least, must be run daily. Thus, on several lines many trains run almost empty, especially in winter.

By this arrangement the public is certainly well served and the traffic is encouraged very actively; but, on the other hand, the financial situation of Italian railways belonging to the State—and more or less the same can be said of private companies—cannot be very flourishing. The result of the high coefficient of exploitation and high cost of the lines is that the traffic barely pays an interest of 1.6% (see Appendix) on the invested capital, and for some private lines there is a deficit; so that the State is obliged to pay annual subsidies of from $1000 to $3000 per mile of line. In such cases, however, after 50 to 70 years the lines become State property.

Italian Railway Policy.

Although from a purely financial point of view this policy may not seem satisfactory, the results from the standpoint of the general national interests are very important.

Many regions of Italy, especially in the South, were still

very backward up to some years ago; agriculture was very rudimental and the population poor and ignorant.

The construction of State railways was a national duty, in order to bring moral and material progress into those regions, regardless of high cost of the lines, which were very difficult to build owing to mountains, ravines and malarial zones.

Thanks to this provident policy, the State railways, with their "differential tariffs", have cemented the political unity of Italy and have given an enormous impetus to commerce. By making the communication easy between the northern and southern provinces, and by charging very low rates, the exchange of the agricultural and industrial products of the respective regions has developed rapidly, and the progress has increased more rapidly still, since the principal railways came entirely under State control. There has been, undoubtedly, a marked improvement in trade all over Italy and a better understanding and good feeling between the people of the different regions of the Peninsula.

Thus, although from a financial point of view the results of State management are very modest and the coefficient of working expenses is high, the Nation does not complain, as it considers the railway expenditures in the same light as those necessary for the Army or the Navy. In Italy, at least, all three administrations are equally indispensable for the very existence of the Nation, regardless of purely financial considerations.

Owing to this policy, regions that for centuries have been subject to a systematic abandonment—if not actual spoliation, while they remained under semi-foreign rulers—are now beginning to develop considerably. Agriculture is improving steadily everywhere, but especially in the South, and new industries are being started, especially in the North. The railways, with their low rates, are a great help in exchanging the products of the different provinces.

Private and State Management.

The most marked improvements, however, have taken place since the advent of the State Railway Board, in 1905.

Before that time, the railways, although for the greater part belonging to the State, were worked by three private

companies, the "Mediterranean", the "Adriatic" and the "Sicilian" R. R. Cos.

The interests of these companies were different from those of the State. Each company worked its system with the object of getting the largest revenue with the smallest expenditure; therefore, tariffs were kept at the highest rate allowed by law, trains were slow and barely sufficient for the local needs, the rolling stock was old and not kept in good repair, and the personnel was under-paid and dissatisfied. Thus, both the public and the personnel had continual grievances against the railway companies. Strikes and systematic hindrance to the service—or "ostruzionismo", that is, literal application of by-rules, by which there was great delay in the running of trains—were becoming alarmingly frequent. Parliament protested; several Ministers had to resign; and in 1905, when the contracts with the private companies expired, they were not renewed.

The State took over the control of all its own railways, and of a few other private lines necessary for the public interests.

This was a daring act and was especially risky from a financial point of view. Happily the Government was very lucky in securing the services of a most competent specialist in railway administration, in the person of Comm. Riccardo Bianchi, formerly General Manager of the Sicilian Railways, who was given sufficient liberty of action to meet the many and serious difficulties which had to be overcome. The State administration, under the guidance of its able president, was brought rapidly to a very satisfactory point. The lines were put in good working order by renewing the permanent way, doubling many trunk lines and sidings, and improving the stations and workshops. Then the rolling stock was renewed and augmented, more and faster trains were run on the main lines, and third-class carriages were attached to all trains. The tariffs, also, were rearranged, in order to facilitate the transportation of agricultural products for long distances, and a "differential tariff" for passengers also was started, by which the rates per mile diminish rapidly with the increase of the length of journey.

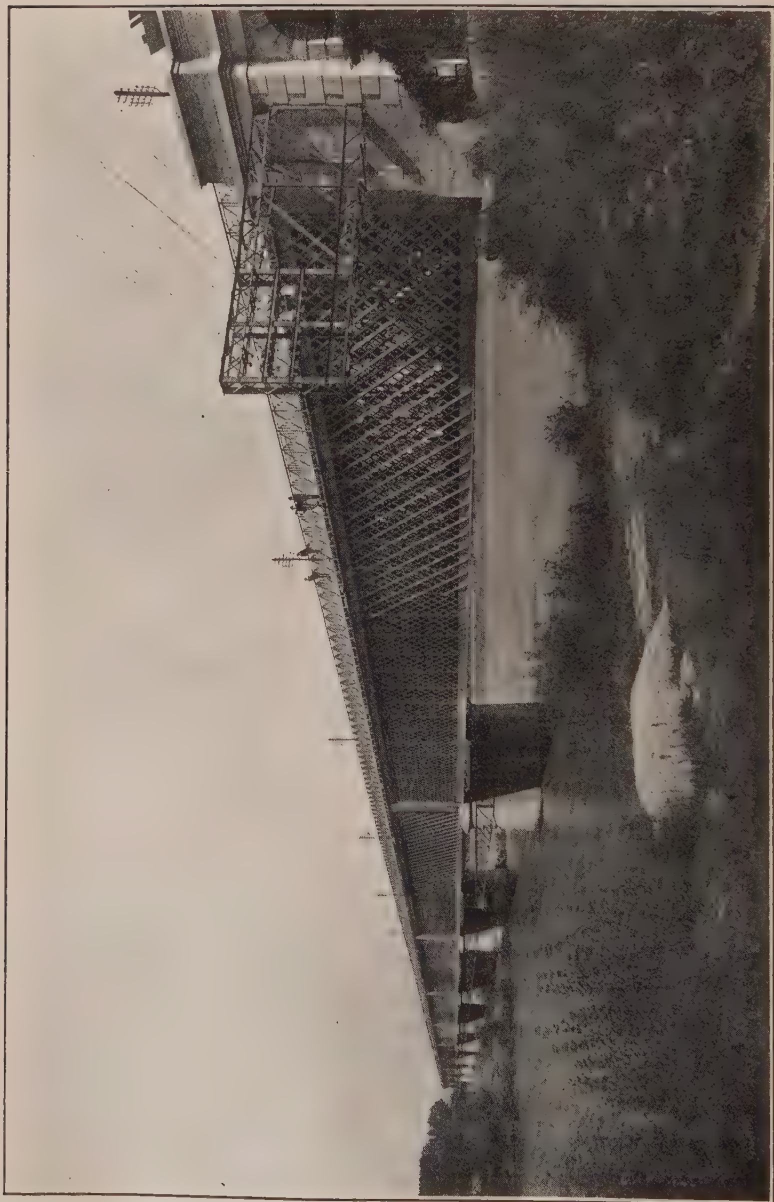

Fig. 2. Genoa-Milan Line. Lattice-Girder Bridge for Railway and Ordinary Road over the River Po at Mezzanacorti. Eleven Spans of 333 Feet Each.

All these reforms gave immense satisfaction to the public, which being encouraged to travel and having better and cheaper means for the transportation of goods, was able to start new industries and extend the centers of business. The National wealth and the railway revenue increase compensated amply for the increasing expenditure, which, notwithstanding all drawbacks, is well below the revenue.

Fig. 3. Milan-Bergamo Line. Steel Arch Bridge over the River Adda at Paderno. Span 360 Feet.

The conditions of the "personnel" were also greatly improved, so that strikes became more rare and easily arranged, and peace, as far as possible, was restored between employes and employers and the service greatly benefited.

Thus now, after ten years of State railway management, the improvements for the public have been so marked, that no one would wish to return to the old regime of private control.

TECHNICAL CONDITIONS.

From a technical point of view, Italian railways are of great interest for the large number of bridges, viaducts and tunnels, which are a consequence of the hilly character of the country, and for the traction, either by electric or by steam locomotives.

Fig. 4. Lecco-Sondrio Line. Granite Arch Bridge over the River Adda at Morbegno. Span 236 Feet.

Permanent Way.

(a) Bridges. For very large span bridges, steel girders or metallic arches are a necessity, and among these the most notable are the steel girders of the several bridges across the Po (Fig. 2), and the great steel arch bridge of Paderno across the Adda (Fig. 3), with a 360-foot span (110 meters).

However, except in these special cases, Italian engineers prefer, whenever possible, technically and economically, to use masonry bridges, which although more costly to construct do not require much upkeep, and practically last forever. The

Fig. 5. Bologna-Brindisi Line. Concrete Arch Bridge over Fiume Rosso. Span 100 Feet.

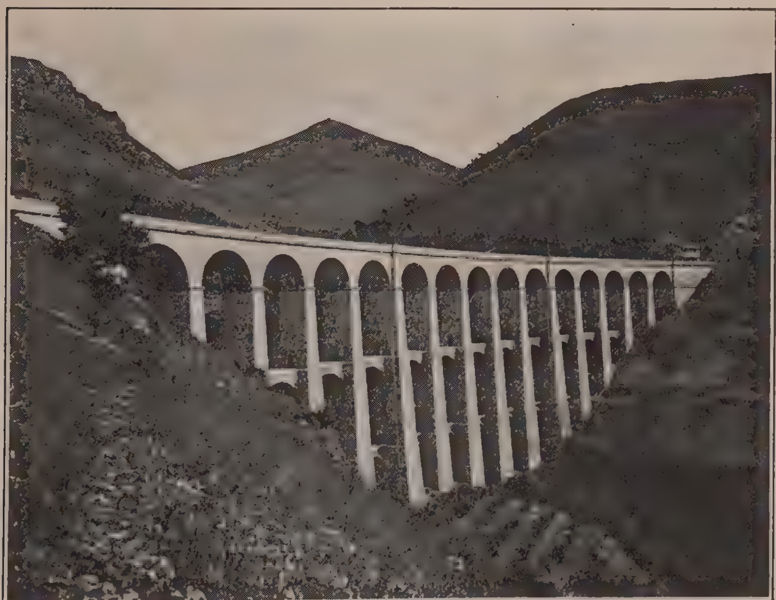

Fig. 6. Roma-Sulmona Line. Viaduct at Ponte Nuovo.

most notable masonry bridge is that of Morbegno (Fig. 4), over the River Adda, with a span of 236 feet (72 m.), built of solid granite, with steel rotules at crown and haunches. There is also a very handsome bridge of three arches made of cement concrete on the Bologna-Brindisi line at Fiume Rosso (Fig. 5), with spans of 100 feet.

Ferro-concrete bridges are in favour only for small spans, as some fears are entertained for spans above 50 feet (15 meters), owing to the possibility that vibrations may diminish adherence between concrete and iron. However, on some secondary lines, ferro-concrete arches of 100 feet span are now in construction.

(b) Viaducts. The deep valleys often spanned by the railways across the Apennines required the construction of many high viaducts, some, very important; among which those of Poretta, on the Pistoia-Bologna line, deserve special mention. The most important of all, however, is that of Campomorone, on the Genoa-Ronco line, with a height of 210 feet (65 m.); and next to it is the viaduct of Ponte Nuovo about 200 feet high including foundations, of the Rome-Sulmona-Isernia line and the Cuneo-Ventimiglia line now in construction.

(c) Tunnels. It is in the matter of tunnels, however, that Italian railways offer the greatest interest. Italy is truly the country of tunnels, and Italian tunnel-borers are famous all over the world. Thousands of them were employed in boring the New York underground railways.

Everywhere in Italy we find tunnels, built for a variety of purposes and at widely separated periods, from the Etruscan to the most modern times. There are tunnels for drainage purposes, aqueducts, railways and road traffic. In the Etruscan period hundreds of miles of drainage tunnels were dug. The most notable tunnel of Roman times is that for the outlet of the Fucino Lake, some three miles in length, built under Claudius.

The most important railway tunnels are those through the Alps which connect the Italian railways with those of France or Switzerland. The Mont Cenis Tunnel, the Saint Gothard Tunnel and the Simplon Tunnel are well known, the latter, nearly 12 miles long (19 kilometers), being up to now the longest in the world.

Across the Apennines there are also very important tunnels, both for their great length—for example, the Ronco Tunnel, between Genoa and Ronco, nearly 6 miles long (9 kilometers), and for the great difficulty of excavating through exceedingly bad and watery marl. Among the latter may be mentioned the tunnels on the Foggia line, where the lateral pressure of the clay was so great that the revetment was crushed three times, till at last it was made 10 feet (3 meters) thick. The Gattico Tunnel, on the Domodossola line, was also excavated through very bad and watery ground, and it was necessary to use compressed-air caissons to overcome the inrush of mud in some exceedingly difficult sections. But on this subject the special report on "Tunnels Recently Built in Italy", presented also to the Congress, may be consulted. So it is not necessary to enter into further details here. However, the rapid advance in driving some tunnels is worth mentioning. On the new Rome-Naples lines an advance of 25 to 30 feet per day was made at each heading, and in the Murgie Tunnel, cut through fissured limestone, the extraordinary advance of 33 feet per day was often reached.

Locomotives.

The other interesting feature of Italian railways, besides bridges and tunnels, is the problem of traction, especially with electric locomotives.

As already stated, the lines are, in general, through rather hilly and, in many places, even mountainous country—requiring gradients of 1 in 40, and in some short sections of 1 in 33, and even 1 in 28—the hauling of trains, therefore, offers great difficulties, both technically and financially.

When the new State administration took over the lines from the private companies in 1905, besides finding the rolling stock, and especially the locomotives, in a very dilapidated condition—as they were of rather old types and in bad repair—it was confronted by a sudden and rapid increase of traffic, which increase continued steadily, till in 1913 it was quite 70% higher.

Thus the problem of traction was aggravated not only by the material difficulties of the profile of the line, but by the fact that the antiquated and well-worn locomotives were not able to respond to the needs of this sudden increase in traffic.

The Director General, Signor Bianchi—who, fortunately, besides being a clever railway manager, was also a specialist in locomotive matters—rose to the occasion and rapidly overcame also this difficulty by adopting new types of steam locomotives for the traffic on ordinary lines, and electric locomotives on very steep inclines. Thus he solved also the problem of the great cost of coal, for hydro-electric power in Italy, thanks to the abundance of waterfalls, is quite cheap.

Steam Locomotives.

Of the steam locomotives, it will be sufficient to give a rapid and concise description. They may be divided into the following principal groups:

(a) Locomotive for Very Heavy Gradients. Type 0-5-0, Group No. 470, built by "Società Anonima Officine Meccaniche", of Milan, in 1911.

The locomotive has ten coupled driving wheels, with four compound cylinders, and presents these characteristics:

Boiler:		
Grate surface	sq. feet	37.75
Heating surface	sq. feet	130
Plain tubes (1.85″)	number	273
Total heating surface of the tubes	sq. feet	2,160
Total heating surface	sq. feet	2,540
Working pressure	lbs. per sq. inch	228
Diam. high pressure cylinders	inches	14.75
Diam. low pressure cylinders	inches	24
Stroke	inches	25.6
Diam. of driving wheels	inches	53
Weight of locomotive in service	lbs.	165,000

(b) Locomotive for Fast Express Trains. Type 2-3-1, Group No. 690, constructed by Ernesto Breda, of Milan, in 1911. It is a superheated steam locomotive, with 6 coupled wheels, forward bogie and "Bissel" back trailer.

It was built to increase the speed of the express trains on main lines.

The weight of the driving axles was brought from 15 to 17 tons, with a possibility of bringing it up to 18 tons by changing the weight on the two trucks. The boiler and machinery

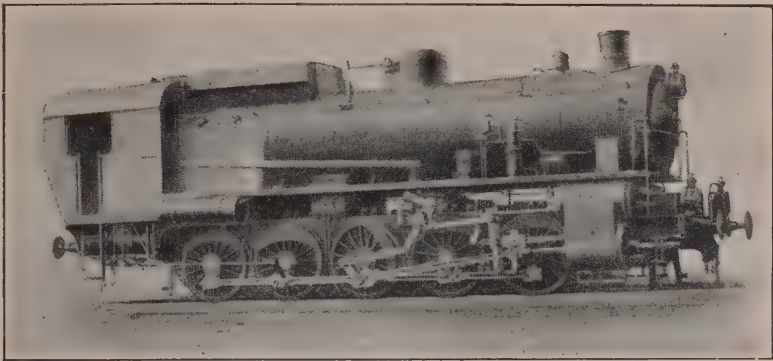

Fig. 7. Locomotive for Very Heavy Gradients. Group No. 470.

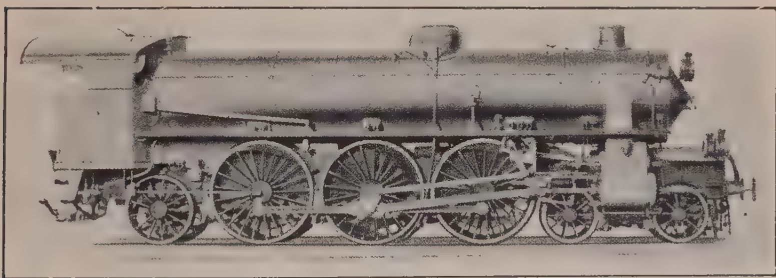

Fig. 8. Locomotive for Heavy and Fast Express Trains. Group No. 690.

Fig. 9. Locomotive for Mixed Passenger and Fast Goods Train. Group No. 740.

are larger than in the preceding types. This locomotive is of the simple expansion type with four cylinders working on the same driving axle, and has a Schmidt superheater.

Principal Data.

Boiler:		
Heating surface (non-tubular)	sq. feet	172
Grate surface	sq. feet	37.75
Evaporating tubes (2.05″)	number	155
Evaporating tubes (5.23″)	number	27
Heating surface of tubes	sq. feet	2,100
Heating of superheater	sq. feet	900
Total	sq. feet	3,000
Working pressure	lbs. per sq. in.	171
4 cylinders—diam.	inches	17.8
stroke	inches	26.8
Diam. of driving wheels	inches	80
Weight of locomotive in service	lbs.	193,000
Adherent weight	lbs.	113,000
Weight of tender in service	lbs.	110,000

(c) Locomotive for Mixed Passenger and Fast Goods Trains. Type 1-4-0, Group No. 740 (Fig. 9), built by Gio. Ansaldo & Co. of Sanpierdarena, presents these characteristics:

Boiler:		
Heating surface (non-tubular)	sq. feet	130
Grate surface	sq. feet	30
Boiler tubes (2.0″)	number	135
Boiler tubes (5.1″)	number	21
Heating surface of tubes	sq. feet	1,540
Heating surface of superheater	sq. feet	466
Total heating surface	sq. feet	2,100
Working pressure	lbs. per sq. in.	170
Diam. of cylinders	inches	21.2
Stroke	inches	27.6
Diam. of drivers	inches	53.5
Weight of locomotive in service	lbs.	147,000
Active adherent weight	lbs.	125,000
Weight of tender in service	lbs.	68,500

Electric Locomotives.

The distinctive feature of Italian electric locomotives is their operation by the tri-phase system. It was adopted for the first time on the "Valtellina Line", between Lecco and Sondrio, and since extended to the Genoa-Ronco, Savona-Ceva, and Bussoleno-Modane lines—a development of 280 km. (174

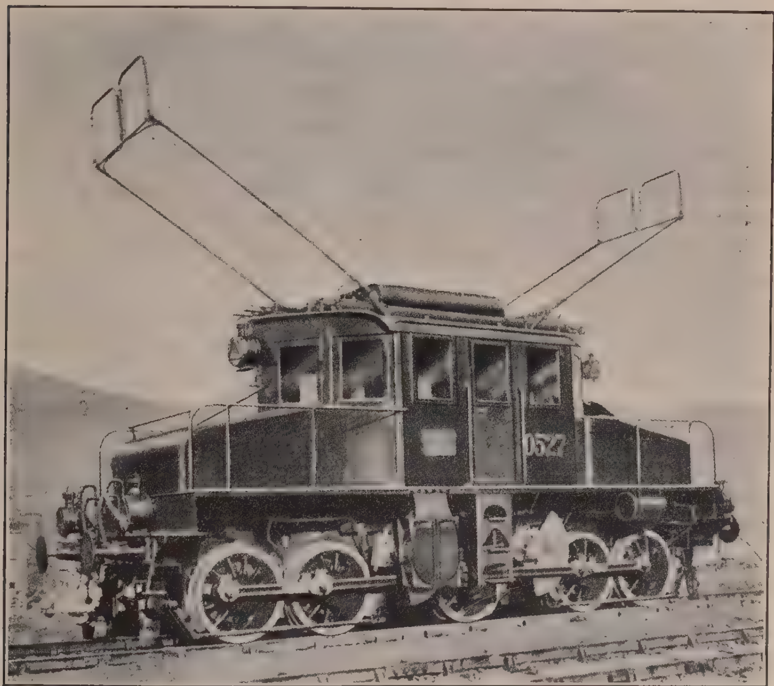

Fig. 10. Electric Locomotive Employed on Mountain Lines. Tri-phase, 2000-HP. Motors. Group No. 500.

miles),--where there are gradients up to 1 in 40, and very long tunnels, where smoke is a serious drawback.

For instance, in the Ronco Tunnel, 9 kilometers long (about 6 miles), and the Mont Cenis Tunnel, 13 kilometers long (about 8 miles), the smoke difficulty was so serious that, notwithstanding artificial ventilation on the "Saccardo" system, cases of asphyxia among the drivers and stokers were not rare, and once a very bad railway accident was caused by asphyxia.

With the electric locomotives, all these difficulties were overcome. Water power being so cheap, it was possible to haul trains up these inclines at double the speed hitherto acquired, thus doubling the potentiality of the line and solving the problem of congestion of traffic, which was becoming very pressing. This alone was a very great accomplishment, as it avoided the immediate need of new lines, which would have required heavy expenditure.

It may be said that electric traction on the tri-phase system, as adopted on the four lines mentioned, has been such a success that not only is it spreading in Italy, but has been copied since by the Swiss State Railways for their Simplon and Lötschberg lines, both with heavy inclines, although not so steep as on the Savona-Ceva and Mont Cenis lines.

For these reasons—the rapid increase of the traffic on mountainous lines and high cost of coals, compared with the low cost of hydro-electric power—this tri-phase system will be applied to all the lines crossing the Apennines, and especially to the group, Pistoia-Bologna, Terni-Aquila, Sulmona-Isernia, in Central Italy, and other lines in Calabria, all belonging to the State railways.

On private lines, electric traction on the mono-phase and tri-phase systems has also been applied, but not on such a large scale as to the Genoa-Ronco and Bussoleno-Modane lines, which are now the most important of Italy, and models of their kind.

The best electric locomotives in use belong to the Group No. 501, Type 0-5-0 (Fig. 10), working on the tri-phase system and were built by the Italian Westinghouse Co., of Vado Ligure, since 1908. At present there are in service 152 of these locomotives, and 40 more are in construction.

They work at 3000-volts tension with 15 periods. They have five coupled driving axles and weigh, complete, 60 tons. Their maximum length is 31 feet, and they are provided with two 1000 hp. motors. To make it easier to pass sharp curves, the two extreme axles have an 8-inch lateral movement, and the middle wheel is without rim. The motors can be united in parallel or in series and give two speeds, viz., 16 and 31 miles an hour (25 and 50 km. per hour).

The apparatus to put the motors in parallel or in series,

to work the starting rheostat, etc., has electro-pneumatic control, and is made in such a way as to command several electric locomotives from the first one.

These locomotives, coupled one at the head and another at the tail of a train weighing 400 tons (Fig. 11), can go on an incline of 1 in 40 at the normal speed of 50 km. (31 miles) per hour, and in case of having to stop for some closed signal, can start again and attain their normal speed of 50 km. in less than 3 minutes.

If necessary, they can also attain a maximum speed of 70 km. (43 miles) per hour on this incline, but then if they have to stop they cannot re-gain the speed of 70 km. for a very long time, so there would be a delay in the arrival of the train and a disturbance of the traffic. For this reason, the normal speed of 50 km. was adopted on heavy inclines, which is high enough, considering that it is almost equal to the commercial speed on Italian lines having gradients of 1 in 100.

When coming down, the motors act as generators of current, and thus about 50% of the energy is actually utilized for hauling up another train. By this arrangement, the braking of the down-going train is done by the electrical apparatus and not by the usual brakes, which are kept open, and the saving in tires and brake-blocks is quite notable.

Thus, by the adoption of electrical traction, the drawbacks of lines with heavy gradients have been practically eliminated. Naturally, there is a greater expenditure of energy, but this being supplied by water power—which in Italy is abundant and very cheap—there is ample compensation in the advantage of being able to carry on mountain lines double the number of trains, and thus doubling the efficiency of the line.

In reality, the result is as if heavy gradients and mountains did not exist. This will have a great influence on the laying out of new lines in mountainous districts. Instead of having to lengthen the line and encounter heavy cuttings and long tunnels, in order to obtain easy gradients, by the adoption of electric traction, as used on Italian lines, gradients of 1 in 40 are quite acceptable even on lines with heavy traffic, thus a great saving, both in the cost of construction and exploitation, will be realized by means of hydro-electric power.

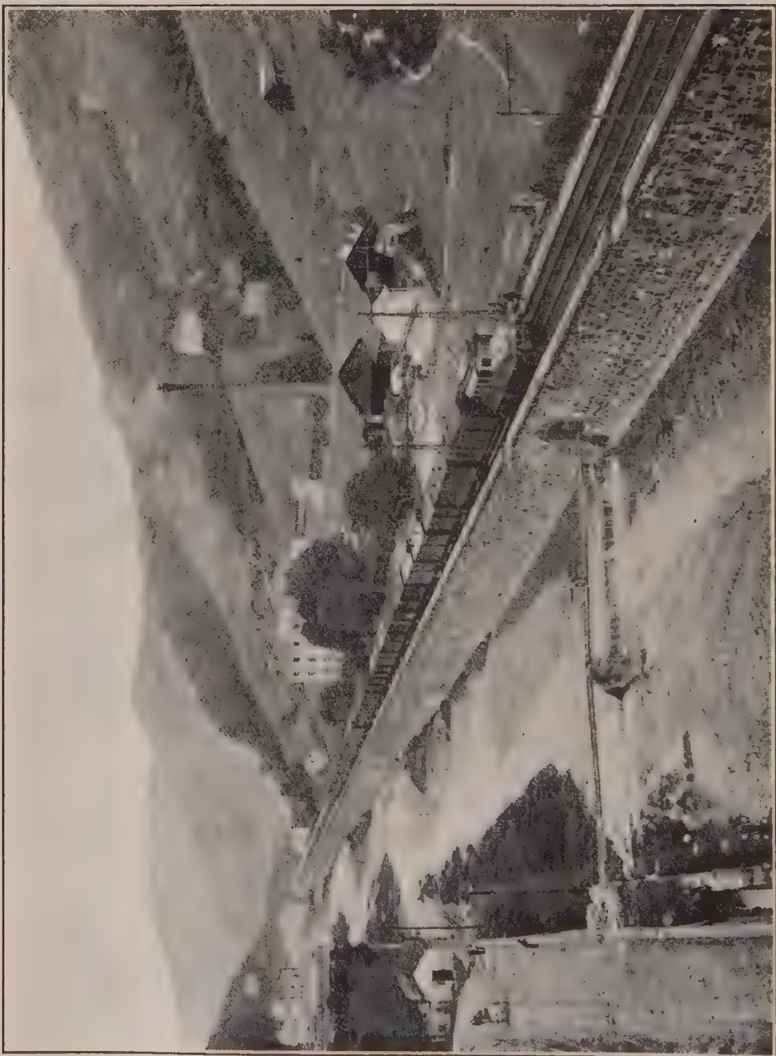

Fig. 11. Electric Locomotive Train on the Genoa-Ronco Line. Two Locomotives Propel a 400-Ton Train up a Grade of 1 in 28 at 31 Miles per Hour.

This valuable use of electric traction will have a far reaching social influence on the progress of many mountainous Provinces of Italy—especially in Calabria, still very backward owing to the scarcity of railways—where the difficulties of steam traction are insuperable and which electric traction, coupled with hydro-electric power, will overcome completely.

Thus electric locomotives will prove an enormous blessing in hilly and mountainous regions, and will contribute greatly to their material progress.

CONCLUSIONS.

It is very difficult to say in general terms whether State management of railways is to be encouraged or not. But as far as it concerns Italian railways—and considering how matters stood up to 1905—it would have been almost impossible to continue under private management; thus State administration became automatically an absolute necessity.

On the other hand, it must be said that in a country where Parliament is all powerful, State management is rather risky, especially from the financial point of view and in regard to the discipline of the personnel.

It was feared at the beginning that Parliament (which in Italy meddles even with the stopping of express trains at unimportant stations, or with transferring a "shunter" from one yard to another because he might belong to an opposing electoral party) would be a cause of great difficulties, if not of the utter failure of State management of railways. So the whole Nation was very anxious about the results of the new administration.

Happily, the Government was very wise in appointing Comm. Riccardo Bianchi as President of the Board of Directors—a man of great experience and firmness, coupled with exquisite tact—who proved to be the right man in the right place.

To this responsible position of President was added that of General Manager, and he was given a certain degree of independence from political influence, as the Board of Directors, over which he presided, was free to do what it considered best

in the interest of the service and of the public, provided, only, that the Minister of Public Works, who is responsible before Parliament, did not "veto", the resolutions of the Board within 48 hours of being notified of their passage.

Thanks to the ability and good intentions of many of the Ministers that were in power during the ten years of State control, and thanks to the great personal sympathy and high esteem that was felt for Comm. Bianchi by all the leading men of Italy, and also by the railway staff—as was demonstrated when he completed his ten years of office—political influence was sufficiently checked to enable the new administration to overcome all difficulties, with the result that the railway service improved immensely; its rolling stock is now quite up to the standard of the best railways in Europe, tariffs are low and help to develop the natural resources of the country, and the Italian people would not change from the present state of affairs and go back to private control as it existed in 1905, before the State management was inaugurated.

In conclusion, it may be said that under the conditions existing on Italian railway lines, and owing to the need of the Nation to bring up to date many of its outlying and still rather backward Provinces, State management—at least, during the first ten years—has been decidedly a great success.

Let us hope it will continue to be so in the future.

APPENDIX.

In order to make clear to our American colleagues the financial administration of Italian State Railways—which are as efficient and economical as any other—and to make the balance sheet for these railways comparable with that of the best European railway administrations—such as those of France and England, managed by private companies, and those of Germany and Belgium, managed by the State, and usually taken as models—it is necessary to take into account the following circumstances, which are peculiar to the Italian State Railways and do not exist, or at least exist in a much smaller degree, on American railroads.

Owing to these peculiar circumstances, some corrections ought to be made in the pure arithmetical results of the balance sheet, in order to make the different items more homogeneous with those of American railroads. In this way they will be comparable; otherwise, they would be quite misleading.

(1) The Revenue ought to be augmented by these items:

(a) To compensate for the absence of State subsidy (granted to all private shipping companies) for the State steam navigation done by the State Railway Board, and for the service on the secondary Sicilian Railway lines	Lire 3,878,000
(b) To compensate for the services which the State gets free of cost (such as postal service and transportation in case of earthquakes or other calamities) or at rates far below working expenses, naval and military transports, inland emigration, Sicilian sulphur, etc., and which no private company would do without proper compensation [1]	Lire 30,000,000
Correcting sum to be added to Revenue in order to make it comparable with that of French, German and English railways systems	Lire 33,878,000

[1] The different branches of the Government put to the charge of the State Railway Administration many services that are paid for in other Nations; for instance, the post office does not pay a cent for the

(2) The Expenditure ought to be diminished by these items:

(c) To expenditure accounted in 1913-1914 which really belongs to 1914-15	Lire 3,434,000
(d) To difference in cost of coals, owing to greater freight from England, in comparison to the cost of coals for French, German and English railways	Lire 20,000,000
(e) To greater working expenses due to the heavy gradients that prevail on Italian lines compared to French, German and English railways	Lire 58,000,000
Correcting sum to be taken off from Expenditure in order to make it comparable with that of French, German and English railways	Lire 81,434,000

(3) The capital expenditure for the construction of Italian railways, in order to make it comparable with French, German and English lines, ought to be reduced by Lire 1,000,000,000, that is, from Lire 5,559,000,000, which was their actual cost, to Lire 4,559,000,000, as about 6000 kilometres of secondary and mountain lines, or those lines built in regions where traffic cannot de-

carrying of mails, mail-vans and travelling sorting-vans; the Army and Navy send materials and personnel over the lines at tariffs so low that they do not cover actual working expenses; the Ministry of Interior, in cases of national calamities, such as earthquakes, floods, etc.—unfortunately not rare during the last few years—orders that persons, provisions and materials to help the people or to reconstruct the damaged towns and villages shall be carried free of charge; the Minister of Agriculture and Commerce, to facilitate the migration of labourers from one region to another during certain periods of the year, to encourage cultivation, or to help the sulphur and other industries, orders that special rates below cost shall be granted, etc. Besides, all Members of Parliament and their families, all railway servants, their families and relatives, and a large proportion of Government employes and other persons are granted free passes on the State Railways; newspaper people and their families travel at a reduction of 75% on the usual fare, and many travel free, etc.

All these circumstances ought to be taken into consideration when comparisons with other railways are made, as they form a considerable item of expenditure without corresponding revenue.

velop, should have been built with narrow gauge (0.95 metres, or 3 feet 1½ inches) and reduced curves, instead of with the standard gauge (1.445 metres, 4 feet 8½ inches) and curves of ample radius, and which caused more tunnels and viaducts and greater expenditure than otherwise would have been necessary. On these lines a revenue of less than 12,000 lire per kilometre ($2700 per mile) was foreseen; and still for different reasons—not excluding political ones in times of elections—the standard gauge, with its extra initial cost and running expenses, was enforced and is now deeply regretted.

When all these differences between Italian State lines and other European lines are taken into account and properly estimated, as above, and the resulting corrections are introduced into the balance sheet in order to "measure both revenue and expenditure with the same foot-rule as in all the other countries"—otherwise, we compare values not estimated by a uniform standard—the results are as follows:

Extract from the Accounts of the "Italian State Railways" for the Financial Year 1913-1914.

(a) Lines in exploitation—Kilometres 13,600 = miles 8,500.

(b) Balance Sheet, as published.

	Francs	Per Kilometre Francs	Per Mile Dollars
Revenue (R)	610,584,000	44,950	13,750
Expenditure (E)	497,756,000	36,650	11,200
Difference (R—E)	112,828,000	8,300	2,550

Coefficient of exploitation $\frac{E}{R} = 0.815$

	Francs	Per Kilometre Francs	Per Mile Dollars
Cost of lines	5,559,000,000	490,000	125,300
Cost of rolling stock and supplies	1,542,000,000	113,000	34,800
Capital invested (C)	7,101,000,000	522,500	160,100

Interest on capital $\frac{R - E}{C} = 0.0159$ or say 1.60%

(c) Balance Sheet as it should be corrected in order to make it comparable with French, German and English railways.

Revenue corrected (R c)	644,662,000	47,400	14,500
Expenditure corrected (E c)	416,322,000	30,650	9,380
Difference (R c—E c)	228,340,000	16,750	5,120
Cost of lines (corrected)	4,559,000,000	336,000	102,500
Cost of rolling stock and supplies	1,542,000,000	113,500	34,800
Capital invested corrected (C c)	6,101,000,000	449,500	137,300

Interest on corrected capital $\frac{Rc - Ec}{Cc} = 0.0374$ or 3.75%

From this balance sheet—corrected with all fairness and justice so that it may be compared with other railways on the same basis,—appears the healthy structure and careful management of the Italian State Railway Board. And if in reality its net surplus—to be put into the National Exchequer—is not so high as in other more favoured or less democratically-governed nations, it is because those nations have already developed their natural resources; which Italy has yet to develop in many of its central and southern provinces, and especially in Sicily and Sardinia. In other words, railways in Italy are a powerful instrument for aiding national progress and they are charged with many expenses that do not take place in France, Germany, and England. For this reason the results cannot be judged simply by mere arithmetical balance sheets, but must be examined from much higher social points of view. By so doing the Italian State Railways can compare favourably with any European system, either belonging to the State or to private companies.

Paper No. 74

THE STATUS OF INDIAN RAILWAYS.

By

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1. At the end of the year 1913-14,* the mileage of Indian railways open to traffic and under construction or sanctioned was as follows:

	Open	Under construction or sanctioned
5′ 6″ gauge	17,641 miles	932 miles
3′ 3″ (metre) gauge	14,389 miles	821 miles
2′ 6″ gauge	2,174 miles	578 miles
2′ 0″ gauge	454 miles	112 miles
Total	34,656 miles	2,443 miles

The reasons for the adoption and perpetuation of a diversity of gauges cannot be dealt with in this paper at any length, as it is a subject worthy in itself of extended discussion It is not clear why the 5′-6″ gauge was originally fixed upon as the standard gauge for India. The metre gauge came into use later, possibly because the promoters, in view of the difficulty of obtaining capital for Indian enterprises, may have found themselves confronted with the alternative of either having to build a railway of narrower and cheaper gauge than the standard or of not building a railway at all. Once the metre gauge obtained a footing, it is easy to understand that branches and extensions were made on the same gauge. The result was that certain areas came to be considered the preserve of the metre gauge and it is consequently necessary nowadays to make new lines within these areas of the same gauge. The 2′-6″ gauge lines are, almost entirely, feeders to main lines on the 5′-6″ or

* Note. The financial year runs from April 1 to March 31. Thus the year 1913-14 means the year April 1, 1913, to March 31, 1914.

metre gauge. India, being an agricultural country, is peculiarly suitable for the construction of cheap feeder lines, traversing agricultural districts for the purpose of bringing their produce to the main line and, since these lines have been found to be attractive to capital subscribed in India, it is probable that their use will extend. The 2′-0″ gauge is unimportant and has no future. It is unlikely that any comprehensive scheme of conversion from metre to 5′-6″ gauge will be undertaken, in view of the improbability of obtaining either the capital sum required or a remunerative return upon it if obtained.

STATE CONTROL.

2. All Indian railways, with a few exceptions, are more or less under the control of the Government. The nature of the control varies from absolute ownership to a mild supervision coupled with the power of purchase after due notice. The Government also has certain powers of control regarding maximum and minimum rates, matters affecting the safety of working, etc., which are common to most countries and need not be referred to here. The following list shows the varying manner in which railways are connected with the Government. The two items in Class 1 are the State Railways proper and have a preponderating importance. As will be seen below, where the financial results of working are given, their preponderance is even greater than the mileage figures tend to show. The meaning of each item will be explained below.

Class 1. Railways Whose Accounts Pass Through Government Accounts.

I.	State Railways worked by the State	7,264 miles
II.	State Railways worked by Companies	18,568 miles

Class 2. Railways Whose Accounts do not Pass Through Government Accounts.

III.	District Board's Lines	166 miles
IV.	Branch Line Companies assisted by Government	1,420 miles
V.	Companies Lines guaranteed by Native States	721 miles
VI.	Companies Lines assisted by Government	2,646 miles
VII.	Native State Lines	3,643 miles
VIII.	Miscellaneous	228 miles
	Total	34,656 miles

Before proceeding to an explanation of each item in the above list, a brief consideration of the railways coming into Classes 1 and 2 will be made. The railways shown under Class 1 are the State Railways of India and their accounts form part of the finances of the Government of India. All capital sums required by them are provided by the Government, either by borrowing in England or India, or from surplus revenues of the Government, etc., as may be deemed expedient from time to time. In the case of railways shown in Class 2, the relation to the Government is not so close, but owing to the responsibility assumed by the Government for payment of guaranteed interest, etc., in many cases, it assumes a measure of control, which is, however, not so intimate as in the case of Class 1. The above items will now be dealt with *seriatim*:

I. State Railways Worked by the State: This requires little explanation. The railways are the absolute property of the Government; they are officered by Government officers; their revenues are part of the general revenues of the country, and all capital sums required are provided by the Government.

II. State Railways Worked by Companies: These are railways which are the property of the Government but which have, for one reason or another, been leased to private Companies for working. The first railways in India were actually constructed and worked by Companies, under unusually favourable terms as to Government guarantee of interest on capital at a rate of exchange, which proved to be so advantageous to the Companies and disadvantageous to the Government that the earliest opportunity was taken of the provisions of the contract, under which these lines came into existence, to purchase them either by cash payment or by means of annuities terminable after a number of years. Certain of these lines became State Railways, dealt with in item I above, and the others became those now under consideration. The Government has entered into contracts with the Companies, the broad features of which are (1) that the Company shall have a small working capital in the concern on which the Government guarantees interest at rates varying from 2 to 3½%; (2) that the Company shall, in addition, receive a share of the surplus profits earned by their efforts, after meeting a payment for interest on

the Government capital, such share being calculated either on a fixed proportion agreed upon or in proportion to the small capital contribution made by the Company; (3) that the Company shall keep the railway in good order; (4) that the Government shall have power to terminate the contract after due notice, and will then repay the Company's small capital at par. It will be seen that the position of the Government is that of the predominant partner in a business concern. The interest of the Government is to see that fresh capital put into the concern is well spent, that the line and rolling stock are kept in good order, and that a profit is earned by good management. The interest of the Company is mainly in making the most of the railway as a dividend-earning investment during its period of tenure. The policy of the Government is to conclude long term agreements with the Companies and to renew the agreements as they fall in, with possibly a revision of the terms if this is found expedient. The Companies, therefore, feel secure in their position so long as their management is wisely conducted and the arrangement works very well. The Companies' administration of the Government's property is loyally and efficiently carried out, and the result is a substantial addition to the revenues of the Country and, also the declaration of substantial dividends for the Companies' shareholders.

III. District Board's Lines: District Boards have been established in certain localities in India as a step towards giving the inhabitants a measure of control over their own domestic politics. It may be said that they bear the same relation to the country districts in which they are situated as a municipality does to its city. In a few cases they have shown praiseworthy ability and have accumulated surpluses which they have been permitted to invest in the construction of light feeder railways traversing their own administrative area. In such cases the assistance rendered by the Government is practically confined to giving the land required, free of cost, to the District Board and in using its good offices in the preliminary negotiations. The Government takes no share of the profits and only reserves the right to purchase the line in certain contingencies. As a rule, the railway is worked by the main line with which it connects for an agreed upon percentage of its gross earnings. This development of a form of State ownership (since a District

Board is a form of government) is interesting as an example of Indian enterprise and has, consequently, been noticed at greater length than the mileage so built would seem to justify.

IV. Branch Line Companies Assisted by the Government. These Companies are a modern development of Indian industrial enterprise in railway construction undertaken under definite Government encouragement. One of the objects of their creation has been to provide an outlet for the savings of the inhabitants of the country. Indians are shy of investing their savings in industrial enterprises and require definite assurances of profit before they will come forward. The Government, therefore, recently published an ordinance inviting proposals for the construction of branch lines to the existing systems from promoters, and engaged itself, after being satisfied as to the financial prospects of the proposed branch and the reliability of the promoters, to render assistance by giving (1) free land and (2) a guarantee of 3½% on the capital invested; or a rebate out of the net earnings of the main line, with which the branch connects, derived from interchange traffic, sufficient to make up, together with the net earnings of the branch, a sum equal to 5% on its capital. A combination of guarantee and rebate terms may be permitted. In return, the Government retains the right to share equally with the Branch Line Co. all profits above the 5% figure and to purchase the line after a term of years. The success of this agency for financing feeder railways is assured. Apart from 21 branches, aggregating 1420 miles, already in operation under these or similar terms, concessions have been granted to 6 more companies to operate an aggregate of 224 miles, and proposals are under examination involving the construction of 2357 miles of railway at a capital outlay of 40 million dollars. It is interesting that short feeder lines on the 2′-6″ gauge have so far proved most attractive to promoters. The guarantee or rebate clause has very rarely involved the Government in any payment, but, on the contrary, the surplus profit clause has resulted in substantial additions to the Government revenues.

V. Companies Lines Guaranteed by Native States: These Companies are the result of a peculiarity of British Administration whereby certain parts of India are under the rule of native chiefs. In the case of certain progressive States, they have

desired to shoulder the guarantees normally given by the Government and to reap for themselves the benefits arising from railway construction within their borders. Such railways are practically independent of Government control, except in so far as the Government is responsible for the safety of the working of the railway and in the good administration of the railway as forming a part of the Administration of the Native State.

VI. Companies Lines Assisted by the Government: These are lines built by Companies receiving miscellaneous forms of Government assistance other than those described in item IV above. They are liable to be bought up by the Government as their agreements fall in, in the same way as described under item II above. They are practically independent of Government control, except in so far as the Government is concerned in safe working and in eventual purchase.

VII. Native State Lines: It was explained above under item V that certain parts of India are under the rule of native chiefs. Some of these native States are very prosperous, and under an enlightened ruler, surplus revenues may, by Government sanction, be invested in railway construction. In this way a considerable mileage of native-state-owned railway has been built. Some of these railways are worked by the native State, and others are worked by Companies in much the same way as the State railways under item II above. Others, again, are worked by the main system to which they are branches for a percentage of the gross earnings. These lines often enjoy a considerable degree of independence. The Government is interested in the good management of the lines, as forming a part of the native State administration, and exercises control over maximum and minimum rates to be charged, but, on the whole, it may be said that Government control sits very lightly on them.

VIII. Miscellaneous: Lines under this head are those in French and Portuguese territory, etc., and need not be referred to further.

FINANCIAL RESULTS.

3. Taking first the railways mentioned in Class 1 in the last paragraph, i. e., the State Railways of India, the financial results, in United States dollars, for the year 1913-14 are as follows:

Capital outlay (booked cost)	$1,495,443,000
Gross revenue	188,196,000
Working expenses	100,374,000
Net revenue	87,822,000
Percentage of working expenses on gross revenue	53%
Percentage of net revenue on capital outlay	5.9%

If the State Railways were a private business concern, the net revenue of 87.8 million dollars would be available for the declaration of a dividend, etc. It was actually applied as follows:

Interest charges on capital borrowed for direct application to works and also for purchase of railways	$46,278,000
Annuities in purchase of railways	13,015,000
Payments in redemption of capital	4,833,000
Total charges on net revenue	$64,126,000
Net profit to Government from State Railways	$23,696,000

Although the accounts of the railways mentioned in Class 2 in the last paragraph do not pass through Government accounts, their results of working are available for addition to the above figures in order to view the results of working the entire body of Indian Railways considered as a whole. The financial results for the year 1913-14 are as follows:

Capital outlay (booked cost)	$1,650,300,000
Gross revenue	211,951,000
Working expenses	109,768,000
Net revenue	102,183,000
Percentage of working expenses on gross revenue	52%
Percentage of net revenue on capital outlay	6.2%

Comparison of these figures with those for the State Railways alone, given above, show the preponderating importance of the State Railways; in fact, the State Railway Administration controls railways on which the capital outlay is 90% of that of all Indian Railways and whose gross revenues are 89% of those of all Indian Railways.

STATE RAILWAY ADMINISTRATION.

4. The State Railways are controlled by the Railway Board, consisting of a President and two Members. The State Rail-

ways are divided up into eleven separate concerns, of which three are worked by the State and eight are worked by Companies in the manner described in paragraph 2, items I and II, respectively. Each of these railways is administered by an Agent (General Manager), who is responsible to the Railway Board for the efficient working of his railway. A system of delegation of powers places the Agents in an independent position, for all practical purposes. Broadly speaking, the object aimed at is that the Agents shall settle for themselves all details of management and the Railway Board shall possess control over major questions of policy and finance. The Railway Board with their staff form a distinct Railway Department of the Government of India, the portfolio of which is held by the Member of Council who has charge of the Commerce and Industry Department. The Government of India, again, is responsible to the British Government, in the person of the Secretary of State for India. Here again, a system of delegation of authority, from the Secretary of State to the Government of India and from the Government of India to the Railway Board, has resulted in a workable scheme wherein only questions of the first importance need to be referred to higher authority. A slight complication is introduced by the fact that all the eight Companies which are engaged in working State property are constituted in England, and the Boards of Directors of these Companies naturally exercise authority over the Agents of their railways. Smoothness of working is assisted by the fact that an Official of the India Office is appointed to sit on the Board of Directors of the Companies, and that by a delegation of their powers, the Directors are usually content to leave the management of their property in India to the Agent, subject to their retaining control of important matters.

In regard to the future, little can be said. The State already owns 90% of the railway property in India, and if it chooses to exercise the power it possesses under the purchase clauses of its agreements with the remaining 10%, can become the owner of all railways in India, in time. Whether such powers will be exerted when the time comes, as each agreement falls in, will probably be determined by the circumstances of

each case on its own merits. There is no reason to regret the policy of acquirement in the past, as the State Railways are returning handsome profits to the Government. The strong position they occupy will be augmented as the payment of terminable annuities for the purchase of railways ceases. The capital value of the State Railways is believed to be considerably in excess of the booked value, owing to the policy pursued of applying certain sums from revenue to works involving a degree of betterment.

Paper No. 75

THE STATUS OF CHINESE RAILWAYS.

By

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A short account of railway history in China is necessary to an understanding of the present status of Chinese railways.

The first definite plan for a railway in China was a petition by the foreign merchants in Shanghai, mostly English and American, dated July 20, 1863, to the then Governor of the Province of Kiangsu, H. E. Li Hung Chang, asking for the sole right to build and operate a railway from Shanghai on the sea to Soochow, the capital of the Province, sixty miles due west. The petition was not granted, Li maintaining that railways to be beneficial to China must be owned and operated by Chinese. Not until many years later was China prepared for the reception of foreign ideas. In 1864, Sir McDonald Stephenson, an eminent British engineer, arrived in China, on his own initiative, to impress the advantages of railways on China. He located on paper an ideal railway system for China as a new and undeveloped country. Knowing but little of China or its peoples, he did not realize that China was old, densely populated, with well defined trade routes, and that no expert was necessary to locate main trunk lines. They were obvious to even a casual student of China's trade and geography. Sir McDonald Stephenson's scheme was received with thanks and all courtesy by the Chinese Government, pigeonholed, and never disinterred.

The next scheme was the Woosung Railway, from Shanghai on the Huangpu River to Woosung at its mouth, a distance of twelve miles. To circumvent the Chinese objections, the


MAP OF CHINA
SHOWING THE
PRESENT
RAILWAY SYSTEM
0 50 100 150 200
English Miles
Railways in operation
Railways under construction - location or for which agreements have been signed
+ + + + + Railways proposed
BRITISH
GERMAN
Indicates the nationality of the syndicate furnishing the necessary capital for the work
THIBET
KAN-SU
SHEN-SI
SHAN-SI
CHILI
SHAN TUNG
HO-NAN
HU-PEI
NGAN HWEI
SZE CHWAN
KWEI-CHAU
HU-NAN
KIANG-SI
CHE-KIANG
FO-KIEN
KWANG-SI
KWANG TUNG
YUNNAN
TONG KING
SHENG KING
LOLOS
YELLOW SEA
GULF OF CHILI
FORMOSA STRAIT
FORMOSA JAPAN
YELLOW RIVER
YANGTZE RIVER
WEST RIVER
PEKING
Tientsen
Taku
Tong Shan
Shanhaikwan
Mukden
PORT ARTHUR (JAPAN)
Chen Te fu (Jehol)
Chung Kia Kao (Kalgan)
Kweihwacheng
Ta Tung
Taiyuen fu
Cheng ting fu
Techau
Weihsien
Chifu
Weihaiwei (British)
Lanchau fu
Pingliang fu
Tungkwan
Honan fu
Sianfu
Hsiang Yang
Kuang Sui
Kwei chau fu
Hankow
Chengtu fu
Chungking
Kiating fu
Ta kia pu
Nan chang
Chang sha fu
Chang te fu
Yuen chau fu
Nanking
Wuhu
SHANGHAI
Amoy
CANTON
HONGKONG
Pose
Nanning fu
Yunnan fu
Weining
Hanoi
Yam chow
Pakhoi
BELGIAN
GERMAN
BRITISH
FRENCH
AMERICAN
RUSSIAN
CHINESE
JAPANESE
PEKING-HANKOW RY
SHASHI-HSING RY
HANKOW-CANTON RY
GRAND CANAL

right of way was purchased by Jardine Matheson and Company on which to build an ordinary road. The embankment was built, and in January, 1876, rails and rolling stock for a narrow-gauge, light railway arrived in Shanghai and on June 30, the road was opened for traffic for a distance of five miles. On July 1 everyone was invited to travel free for two days. All went well. The people were delighted and traffic was beyond expectation, but the Chinese authorities wanted no foreign railway. On August 3, a coolie, evidently bent on suicide, was run over and killed and the running of trains was stopped. Eventually the Chinese Government bought the railway, payment to be made in three semi-annual payments. On December 1, 1876, the road was opened again and operated the entire distance to Woosung until the last payment was made. Then the Chinese took possession, demolished the road, shipped rails and rolling stock to Formosa, where they rusted away on the beach, and erected a small temple to the Queen of Heaven upon the site of the Shanghai Railway Station.

During 1887 to 1893 there was constructed on the Island of Formosa, then a part of China, some sixty miles of metre-gauge railway, by the Chinese. The alignment and grades were such as to prohibit economical loads and speed, and the construction was of inferior quality. At this point the work was stopped by orders from Peking, and the railway gradually went to pieces until the taking over of Formosa by the Japanese in 1896.

THE KAIPING RAILWAY.

Li Hung Chang became Viceroy of Chihli about 1870; soon afterwards there was organized the China Merchant Steam Navigation Company, with a fleet of coast steamers, Chinese capital and under Chinese management. The officers of the steamers were British. Much coal was needed and only Japanese coal was available. China's vast coal deposits were mined only by Chinese methods, with a small output, and none were available for the supply of ocean steamers. This led to the formation, in 1878, of the Chinese Engineering and Mining Company and to the opening and operating of the Kaiping coal fields by foreign methods with Chinese capital and manage-

ment. This deposit lies near Tangshan, about half way between Shanhai Kwan and Taku at the mouth of the Pei River leading to Tientsin, the port of Peking. These two companies were organized and managed by Tong King Sing with the support of His Excellency Li Hung Chang, Viceroy. To Mr. Tong, however, should be given full credit for originating and carrying to completion this advanced policy, which ultimately gave China a railway system.

The Kaiping coal mines at Tongshan were twenty-nine miles from the nearest point of delivery on the sea, and railways were proposed, sanctioned by the Throne, and C. W. Kinder, M. I. C. E., K. M. G., etc., was appointed engineer. The Imperial Sanction was revoked, and a canal to connect with the Pehtang River was decided upon. This canal could not reach the mines by seven miles, and a tramway with mule power was constructed. Thanks to the insistence of Mr. Kinder, the gauge was 4′-8½″, the standard gauge, thus saving China from the curse and expense of the metre gauge. The tramway and canal were finished in 1881. Still fighting for steam motive-power, Mr. Kinder began to build a locomotive from scraps, the boiler and cylinders from a portable winding engine, wheels bought as old iron, and the frame from channel iron borrowed from the mining company. The cost of construction was £75/0/0. By persistency and the influence of His Excellency Li, permission was granted to finish the "monster", and on June 9, 1881, the one hundredth anniversary of the birth of George Stephenson, this locomotive was christened the "Rocket of China" and at once put to daily use; opposition ceased, and the next year two shunting engines were purchased.

Thus was inaugurated China's railway system. In 1887 the railway was completed from Tangshan, via Tongku, to Tientsin; in 1894, from Tangshan to Shanhai Kuan, and in 1897, from Tientsin to Peking. The Government of China had, by 1898, realized two points regarding the introduction of railways: First, the absolute necessity of railways, and, second, the impossibility of procuring Chinese capital for the building of railways. The Chinese would not subscribe because of a lack of confidence in the Chinese Government, much of this feeling being due to experience.

The Chinese Government still stood fast that foreigners should own no railways in China and that the main trunk lines, at least, should belong to the central government. The result was "The Railway Concessions".

The concessions granted to Russia in Manchuria, to the Germans in Shantung and to the French in southwestern China are on a different basis from the many concessions granted to syndicates proper; principally, because to the Russian, German, and French, the railway was not the end desired, but merely a means to the end, and that end colonization.

The terms of the ordinary concession were more or less as follows. China granted to the syndicate as a contractor, the right to build a definite railway. The Chinese Government issued gold bonds at five per cent interest to cover the cost of construction and equipment, the par value of the bond being 100. The syndicate under-wrote the bonds at 90 and sold them to the public at as high a price as possible. The syndicate constructed the line and was allowed 5% upon the actual cost. As fast as completed, the syndicate had a first mortgage on the railway and equipment. The syndicate was trustee for the bondholder and operated the finished line jointly with the Chinese, the foreign element, however, predominating. A small percentage of the net profits, after deduction of interest and sinking fund, went to the Chinese. The conditions under which the bonds could be redeemed were agreed upon, etc.

In Peking, 1898 was the year of concession hunters. The whole world was represented. Some represented bona fide syndicates. Many represented hopes and were hunting for both concession and syndicate.

Then was seen the difference between the methods of the continental and the Anglo-Saxon. They were all there with any amount of good money behind them. The English and American would not sign until every detail of the agreement was satisfactory. The Belgian or French would sign almost any agreement that gave them the absolute right to the work and then fight out the details later. The continentals then, and ever since, have had the cream of the railway concessions, and they have done the work they agreed to do. The British, also, have done most excellent work in all the railways they have built.

An American syndicate was granted a concession for the Hankow-Canton Railway, did but little work, and later was bought out by the Chinese Government at a "remunerative" figure and the line is now being built by British money and British engineers.

All the railways of China, with the exception of a few short lines usually for some special purpose, are government-owned and government-run. They are all under the Ministry of Communication (Chiao T'ung Pu) located in Peking. On all the railways having a foreign indebtedness, certain positions are filled by foreigners (chief engineer, resident engineers, chief accountant, traffic manager, chief of the mechanical department, etc.), with necessary foreign assistants. The nationality of these foreign employees, in every case, follows the nationality of the syndicate furnishing the capital, except in subordinate positions. From this, one can see the small opportunities there are in China for Americans in railway employment. American participation in the construction of Chinese railways has been, to say the least, unfortunate, and, of course, the non-participation of Americans in this work has militated strongly against the purchase of American rolling stock, locomotives, and railway material.

In regard to the present status of railways in China, there are some six thousand two hundred miles in operation and between eight and nine thousand miles under construction, location, or for which definite agreements between the Chinese Government and foreign syndicates have been signed, for either financing and constructing, or for merely financing. Less than three hundred miles of this amount comes to America. The accompanying railway map of China shows the railways in operation, construction, and proposed. The names of the different nationalities along these lines, such as British, Belgian, French, etc., indicate the nationality of the syndicate furnishing the necessary capital.

The freight rates in China are high,—what the traffic will bear and often a little more. In North China coal is $2.05 for three hundred miles.

PEKING-MUKDEN RAILWAY.

Freight charges per picul (133 pounds) and per ton per mile.

1st class per picul ½ cent, per ton 5 cents per mile.

2d class per picul 1/3 cent, per ton 3½ cents per mile.

3d class per picul ¼ cent, per ton 1¾ cents per mile.

Dangerous per picul 5 to 7½ cents.

The following list shows the more important lines for which agreements have been made:

	Miles
Kerin-Hunchun, joint Chinese-Japanese	240
Kai Yuan-Hailungchen (Branch South Manchuria), Japanese	110
Kungchuling-Itungchow (Branch South Manchuria), Japanese	50
Habin-Shushaie, Chinese	150
Shansi Railway. Tatung-Taiyuan-Ping yao-Pochow-Tung Kwan-Chengtu (Szechuan), Belgian	960
N. W. Trunk Line. Ili-Lanchow 1910; Sian fu 350; Tung Kwan 85; Honan fu 150; Kaifeng 140; Hsuchow 175; Thsing Kiang pu 120; Haichow 70; Belgian	3,000
Chengting-Tehchow, German	110
Hsiang yang Shasi, German	207
Hsiang yang Kuang sui, German	130
Kaomi-Yihsien, German	200
Yenchow Tsaochow Kaifeng, German	230
Yunnan fu-Chungtu fu, La Banque Industrielle de Chine, French	450
Sin yang-Pukow, British-Chinese Corporation	300
Shasi-Hsing-yi, via Changteh-Yuenchow-Kwei yang, British	800
La Banque Industrielle de Chine, French: Sino-French, 60,000,000 francs, Harbor at Pukow; 60,000,000 francs, Yangtze Bridge at Hankow; Railway, Yam-chow (near Pakhoi via Nanning, Pose, Hsing to Yunnan fu)	550

The following notes from the latest available data show the cost of construction, operation, and revenues of some of the railways in operation:

CHINESE GOVERNMENT RAILWAYS.

Peking-Mukden.

Developed from the Kaiping tramway, constructed 1880-1 by C. W. Kinder, C. M. G., M. I. C. E., who also completed the Peking-Mukden line.

Capital—Anglo-Chinese	$49,971,571.43
Cost of construction—	
Lines open for traffic	47,246,706.47
Expenditure capital works from revenue	8,938,970.27
Mileage—607 miles	
Gauge—4 feet, 8½ inches	
Receipts for year 1912	$13,183,638.51
Expenditure for year 1912	3,820,657.23
Number of Passengers—3,495,707	
Tons of Freight—3,450,393	
Passenger receipts	$ 5,257,591.89
Freight receipts	6,850,353.37
Ratio of expenditure to receipts, 28.90 per cent.	

Peking-Hankow.

(Belgian-French)

Construction began in 1898.

Cost of construction	$87,956,765.22
Mileage—755 miles	
Gauge—4 feet, 8½ inches	
Receipts for year 1912	$13,557,713.00
Expenditures	5,246,300.00
Open to traffic in 1905.	

Tientsin-Pukow—Northern Section.

(German)

Construction commenced July 1, 1908.

Capital—German	£5,040,000
Plus temporary loan	912,272
Mileage—453.15 miles.	
Gauge—4 feet, 8½ inches	
Cost of construction—Approximate	£5,000,000

Tientsin-Pukow—Southern Section.

(English)

Construction began February, 1909.

Capital—British-Chinese Corporation	$ 2,847,728.00
Mileage—263 miles	
Gauge—4 feet, 8½ inches	

Peking-Kalgan.

Construction began October, 1905.

Capital Expenditure $10,709,820.00

This capital was all derived from the surplus earning of the Peking-Mukden line.

Engineer in Chief of construction, Jeme Tien-yu. Present Engineer in Chief, K. Y. Kwong.

This line was located, constructed and is now operated entirely by Chinese.

Canton-Hankow.

Construction was begun by an American syndicate, which did a very slight amount of work and abandoned the enterprise on receiving compensation from the Chinese of $6,700,000, gold, in January, 1904.

This line is now being constructed under English and Chinese engineers and with British capital. Mileage, 700 miles.

Shanghai-Nanking.

Construction began in 1904.

Mileage—203 miles
Cost of construction..$26,755,270.00
Source of capital—British-Chinese Corporation
Receipts for year 1912..$ 2,675,943.00
Expenditures 1,704,794.00

Canton-Kowloon.

Construction began (1) British Section, 1906
" " (2) Chinese Section, 1908
Source of capital—
Chinese Section—Government of Hongkong
British Section—British-Chinese Corporation.
Cost of construction—British section..............................$13,284,425.00
" " " Chinese Section 12,594,277.00
Mileage—British Section 22 miles
" Chinese Section 89½ miles

Open to traffic: British Section, October 1, 1910; Chinese Section, October, 1911. British Section, 5 tunnels—150 ft., 7,212 ft., 329 ft., 170 ft., 923 ft. All double track except No. 2; 50 bridges, all double track.

DISCUSSION

Mr. Hsia. **Mr. C. T. Hsia*** stated that Mr. Jameson's paper gives a correct account of the railways of China, but amplified on a few points. After the foundation of the Republic, 1912, the policy was adopted that the railroad lines joining large cities should be controlled by the Government.

All of the railroads, along with the post, shipping, and telegraph, are under the control of the Ministry of Communications. Railroads and the post are being rapidly developed; shipping and the telegraph, but slowly.

The demolition of the Woosung Railroad, mentioned by Mr. Jameson, was not a mistake, as there was a justification in that the contract was for building a highway, not a railroad.

In regard to Americans furnishing rolling stock, etc., to railroads of China, Mr. Hsia submitted extracts from his book, entitled "Modern Transportation in China."

Railroads in China.

With regard to the progress China has recently made in her various means of communication, the advancement in railroad construction is the most prominent feature. The reason for this is to be found in the immense size of her territory, her numerous products and the urgent need of bettering and speeding up her old-established transportation ways.

The first proposal for establishing railroads in China was introduced in the year 1863. The construction of the Shanghai-Woosung Line, 20 kilometers in length, was achieved in 1876; and that of the Kiaping Mine Railway, 15 kilometers in length, in 1881. But the Manchu Government, as well as the people, did not apparently realize the importance and the necessity of the railroads until 1886, when the first part (from Tang-Shan to Tientsin) of the Peking-Mukden Line, was properly constructed and operated. The construction of the entire net of railroads operated today in China may be roughly divided into four periods:

	Years.
First Period	1886-1894
Second Period	1895-1905
Third Period	1906-1911
Fourth Period	1912-1915

During the first period, ending with the year when the China-Japan war took place (1894), China had only 444 kilometers of railroad line in operation.

The second period, beginning at the end of the China-Japan war in 1895, lasted until the year 1905, which marked the termination of the

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Mr. Hsia.

Russo-Japanese war. Towards the end of this period China had altogether 2,842 kilometers of railroads, representing an addition of 2,398 kilometers to the amount belonging to the first period. Thus started the new era of rapid progress in railroad construction in China; for during this period of 11 years, an average of about 218 kilometers was added every year to the existing railroad lines.

The third period, starting with the conclusion of the Russo-Japanese war in 1906, lasted until the downfall of the Manchu Dynasty in 1911. At the end of this third period, China possessed a total length of 4,661 kilometers, showing an increase of 1,819 kilometers within six years. This amounts to an average of 303 kilometers of new railroads constructed each year.

The fourth period begins in 1912, at the birth of the Chinese Republic, and is continuing up to the present day. Although this covers only not quite three years, yet, the total amount of railroad lines in China has been raised to 5,475 kilometers (end of 1913). There are now under construction or preparation about 8,200 kilometers of new lines. This number is divided approximately thus:

(1,500) Fifteen hundred kms. for the Lung-Hai Line.
(1,500) Fifteen hundred kms. for the Tatung-Chengtu Line.
(1,000) One thousand kms. for the Szechuan-Hankow Line.
(1,000) One thousand kms. for the Shasi-Singyi Line.
(1,000) One thousand kms. for the Cheng-Yu Line.
(900) Nine hundred kms. for the Canton-Hankow Line.
(850) Eight hundred and fifty kms. for the Ning-Siang Line.
(450) Four hundred and fifty kms. for the Pukow-Singyang Line.

Therefore, within the next few years the Chinese Government will own and control a total of about 13,700 kms. of railroad lines.

China has suffered in this last period from internal upheavals and disorders which interrupted most of the progressive reforms. However, the development of transportation was not only uninterrupted but was pushed forward and very much is being actually accomplished in spite of all interference and difficulties produced by the political reformation since 1912. This was due in a large measure to the ability of the Minister of Communications, Chu-Chi-Chien, and the present Vice-Minister, Yeh-Kung-Chao, who was then Director General of the Railroads in the Ministry of Communications; they have done the utmost in upkeeping the continued progress of railroad construction in China.

In 1913 the Ministry of Communications created a committee for the unification of railroad accounting. Dr. C. C. Wang, who is now Director of the Railway-Accounting Department, was appointed Chairman of this committee, and Mr. Adams, an expert American railroad man, was appointed Advisor to the Committee. In 1914 a reorganization of the Ministry of Communications was devised by the Minister, Liang Tung-Yen.

Mr. Hsia. The definite plan was carried out successfully the very same year with the net results of increase of the ability of the Ministry, in maintaining as well as financing all the railroads and the other communication systems. These facts show the great desire and the efforts undertaken by the Government for the rapid development of modern transportation facilities in China. It is felt that upon these depend the successful accomplishment of many other important reforms.

Information Regarding the Chinese Government Railways.

Rails of Metric Standard—Length, 9 m. to 9.75 m. Weight, 37 kgs./m. to 42 kgs./m.

Rails of English Measures—Length, 30 ft. Weight, 60 lbs./yd. to 85 lbs./yd.

The specifications call for a limit of carbon of from 0.35 to 0.45 per-cent in the steel rail. The tensile strength of the material should be from 65 to 80 kgs. per square mm., or from 40,000 to 50,000 lbs. per square inch. Most of the rails used are manufactured by the Hang-Yang Iron Works.

Railroad Ties or Sleepers have a cross section of 14 cm. by 22 cm., or 6 in. by 9 in. Specifications call for well-seasoned and carefully creosoted ties.

Cars and Locomotives are built according to the "Standard Diagrams and Specifications," approved by the Ministry of Communications.

Signals.—A uniform system of safety block-signaling has been successfully put into use on all the railroads of China. The main lines and stations are fitted with automatic ladders, while minor lines use ladders handled by man-power.

Maintenance.—Each line of the Chinese Government Railways has one or more shops of its own for the manufacture and repairing of its cars and locomotives. These shops are, generally speaking, of small capacity. Among them the Tang-Shan Shops of the Peking-Mukden Line may be considered at present the largest. This shop has not only the ability of supplying cars and locomotives for its own line, but also to fill in car orders for other railways.

Bridges.—The largest and most famous railroad bridge of China is the Yellow River Bridge of the Peking-Hankow Line. This bridge is all made of steel, having altogether 102 spans and a total length of 3,010 meters. All its piers and abutments are made of steel columns, screwed deeply down into the bottom of the river. Our model, in the Palace of Transportation, represents a steel-truss span and a plate girder span of this bridge.

The second largest railroad bridge is the Yellow River Bridge on the Tientsin-Pukow Line (on the lower side of the river). The foundations of this bridge are of stone and concrete masonry, including many concrete piles, while the body of the bridge consists of steel structures. The bridge

is 9 meters in width, containing two railroad tracks and two sidewalks. Its total length is 1,255 meters. It was started in 1909 and completed at the end of 1912. Mr. Hsia.

Very soon another large bridge is to be built over the Yangtze River as a connection between the Peking-Hankow Line and the Hankow-Canton Line.

Gauges.—All of the Chinese Railroads, except one, are following the normal gauge of 4 ft. 8½ in. or 1.435 m. The Tcheng-Tai Line, 243 kilometers in length, is built according to the narrow gauge of one meter. However, through the means of extensible bogies, the cars running on this railway may be transferred into the Peking-Hankow Line, of standard gauge. The use of the extensible bogies has produced—so far—highly satisfactory results.

GOVERNMENT RAILWAYS—LENGTH OF LINES AND AVERAGE COSTS PER KILOMETER.

Government Railways in Operation	5475 km.
Government Railways Under Construction	8200 km.
Total	13,675 km.

Railways	Length in Km. Main Line	Branches	Cost per Km.
Peking-Hankow Line	1214	101	*$53,065
Peking-Mukden Line	839	151	50,102
Tientsin-Pukow Line	1015	64	81,904
Shanghai-Hangchow Ningpo Line	387	----	57,600
Shanghai-Nanking Line	311	26	78,136
Tcheng-Tai Line	243	------	85,995
Peking-Kalgon Line	201	26	45,826
Kaifeng-Honan Line	185	------	59,300
Kirin-Changchun Line	128	------	46,317
Taokou-Tsinghua Line	150	------	46,323
Canton-Kawloon Line	145	------	84,000
Kalgon-Suiyuan Line	152	------	----------
Chuchou-Pinghsing Line	90	27	50,066
Canton-Samshui Line	52	------	----------
†Tatung-Chengtu Line	1500	------	----------
†Lung-Hai Line	1500	------	----------
†Szechuan-Hankow Line	1000	------	----------
†Canton-Hankow Line	900	------	----------
†Shasi-Singyi Line	1000	------	----------
†Chung-Yu Line	1000	------	----------
†Ning-Siang Line	850	------	----------
†Pukow-Singyang Line	450	------	----------

* Chinese dollar = 50c U. S. money.

† Railways not yet completed.

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GOVERNMENT RAILWAYS, YEAR 1913—TOTAL RECEIPTS AND EXPENDITURES.

	Receipts	Expenses
Peking-Hankow Line	$17,440,000	$ 5,119,000
Peking-Mukden Line	14,400,000	5,727,000
Tientsin-Pukow Line	5,840,000	8,265,000
Shanghai-Nanking Line	3,027,000	1,877,000
Peking-Kalgon Line	2,632,000	1,110,000
Tcheng-Tai Line	2,133,000	1,796,000
Kaifeng-Honan Line	984,000	464,000
Kirin-Changchun Line	674,000	652,000
Kalgon-Suiyuen Line	586,000	275,000
Taokou-Tsinghua Line	548,000	626,000
Shanghai-Fengching Line	531,000	354,000
Chuchou-Pinghsing Line	520,000	340,000
Canton-Kawloon Line	393,000	371,000
Total	$49,708,000	$26,986,000

GOVERNMENT RAILWAYS—SHOPS AND WORKING STANDARDS.

Railway	Shop Location	Number of Employes	Yearly Working Days	Daily Working Hours	Pay Per Day Max.	Pay Per Day Min.
Peking-Hankow	Chang-Sin-Tien	1030	300	9	4.00	0.70
	Liu-Kia-Mio	732	300	9	4.00	0.70
	Tcheng-Chow	189	300	9	4.00	0.70
Peking-Mukden	Tang-Shan	3850	300	9	3.60	0.40
	Koupangtze	449	303	10	3.20	0.50
	Shan-Hai-Kwan (Bridge Works)	605	312	9	2.00	0.30
Tientsin-Pukow	Tientsin	241	310	9	3.60	0.50
	Tsinan	681	310	10	3.00	0.40
	Pukow	50	310	9	3.00	0.60
Shanghai-Nanking	Woo-Sung	284	307	10	2.80	0.30
	Shanghai	841	307	10	3.20	0.30
Tcheng-Tai	Yang-Chuan	143	298	11	3.00	0.60
	Shekiachwan	792	298	11	3.00	0.60
	Tai-Yuan	148	298	11	3.00	0.60
Peking-Kalgon	Ñankow	550	312	9	3.00	0.40
Kaifeng-Honan	Pienlo	280	312	10	2.00	0.50
Taokow-Tsinghwa	Tao-Ching	330	308	10	3.40	0.44
Canton-Kawloon	Kwang-Chiu	194	312	9	2.00	1.20
Kalgon-Suiyuan	Chang-Sui	178	312	9	3.00	0.50
Kirin-Changchun	Chi-Chang	226	312	10	3.60	0.60
Chuchow-Pinghsing	Chu-Ping	248	312	10	4.00	0.40

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GOVERNMENT RAILWAYS—AVERAGE SPEEDS.

	Speed in Kms. per hour
Shanghai-Nanking Line	65.5
Canton-Kawloon Line	56.5
Shanghai-Hangchow Line	51.0
Peking-Mukden Line	50.5
Tientsin-Pukow Line	49.0
Peking-Hankow Line	47.0
Kaifeng-Honan Line	47.0
Tcheng-Tai Line	40.0
Taokow-Tsinghwa Line	39.5
Peking-Kalgon Line	36.5
Kirin-Changchun Line	33.0
Chuchow-Pinghsing Line	32.0

1 Kilometer equals 0. 62 Mile.

GOVERNMENT RAILWAYS—FIRST CLASS PASSENGER TRAINS.

	Fare per Kilometer
Tcheng-Tai Line	$0.048
Kirin-Changchow Line	0.048
Peking-Kalgon Line	0.043
Tientsin-Pukow Line	0.038
Peking-Mukden Line	0.038
Peking-Hankow Line	0.036
Kaifeng-Honan Line	0.036
Canton-Kawloon Line	0.028
Shanghai-Nanking Line	0.026
Shanghai-Hangchow Ningpo Line	0.026
Taokow-Tsinghwa Line	0.025
Chuchow-Pinghsing Line	0.016

I Kilometer equals 0.62 Mile.

GOVERNMENT RAILWAYS—ROLLING STOCK INVENTORY. END OF YEAR 1913.

Railways	Locomotives	Tenders	Passenger Cars	Freight Cars	Total of Units
Peking-Hankow	126	84	242	2,602	3,054
Tientsin-Pukow	82	70	153	1,167	1,472
Peking-Mukden	137	117	306	2,941	3,501
Shanghai-Nanking	31	31	82	288	432
Shanghai-Hangchow (Kiangsu Section)	8	7	43	75	133
Shanghai-Hangchow (Cheekiang Section)	19	13	50	283	365
Tcheng-Tai	51	46	63	496	656
Peking-Kalgon	37	26	60	392	515
Kaifeng-Honan	15	10	38	328	391
Kalgon-Suiyuan	8	4	24	100	136
Taokow-Tsinghwa	10	8	33	166	217
Canton-Kawloon	9	7	31	47	94
Kirin-Changchun	13	11	20	171	215
Chuchow-Pinghsing	12	10	16	183	221
Totals	558	444	1,161	9,239	11,402

Paper No. 76

GENERAL PRESENTATION OF THE PRESENT CONDITION OF THE RAILWAY SYSTEM IN RUSSIA.

By

V. A. NAGRODSKI
Petrograd, Russia

Towards the end of 1914 the railway system of the Russian Empire then in operation, comprising the East China Railway (in Manchuria) presented, without counting the secondary connections, a total length of 71,939 versts (76,745 km. = 47,687 mi.), of which 18,467 km. (11,475 mi.) or 24 per cent are double track. 75,337 km. (46,812 mi.) belong to the railways of general importance; the other 1408 km. (875 mi.) were purely of local importance.

Most of the Russian railways have a gauge of 1.524 m. (5 ft.) width, known as "normal". There are only 4579 km. (2845 mi.) having a gauge for the track of 1.435 m. (4 ft. 8½ in.); 577 km. (358.5 mi.) having a gauge of 1.067 m. (3½ ft.); and 1000 km. (621 mi.) having gauges of 0.913 m. (3 ft.), 0.900 m. (2 ft. 11½ in.), 0.800 m. (2 ft. 7½ in.) and 0.750 m. (2 ft. 5¼ in.).

The grades belonging to the Russian railroads are, barring a few exceptions in the mountainous countries, from 0.008 (0.8%) to 0.010 (1.0%). The radii of curvature most frequently used are those of 400 to 600 m. (1312.3 to 1968.5 ft.). The track consists of steel rails, type vignole, on wide ties (pine, oak). The rails weigh from 30 to 37 kg. per running meter (60 to 75 lbs. per yard).

The principal statistical data concerning traffic and financial results obtained by the most important lines in Russia from 1907 to 1912 are collected in the tables appended to this

paper.* In examining these tables, one can readily notice that almost all the lines increased their traffic and receipts in a rather rapid and regular manner, at the same time decreasing the operating expenses in a more or less systematic way. The annual increase of the traffic of Russian railroads can be set at from 6 to 7 percent, on an average.

A summarized comparison of the results of the operation of the Russian railways for the years 1902 to 1912 brings out the following increases:

1	Length of lines operated	17%
2	Number of travelers per km.	68%
3	Amount of merchandise per km.	53%
4	Total receipts	80%
5	Receipts per km.	54%
6	Total expenses	53%
7	Expenses per km.	31%
8	Coefficient of operation	minus 15% (decrease)

The events which are taking place just now in Russia, having delayed the publication of definite statistics for the year 1913, we shall have to be satisfied with the following prin-

* The years 1904, 1905, 1906 have been omitted from the decennial statistical tables because they could not be considered as normal on account of disturbances in the economic life of the country, caused by the Japanese war and the domestic events which followed it.

Length operated, 68,850 km. (42,781 mi.)
Gross receipts, 1,128,903,198 rs. ($581,385,147)
Operating expenses, 670,594,037 rs. ($345,355,929)
Coefficient of operation, 59.4.
Density of the passenger traffic:
Passenger-km. per km. of the lines, 405,000 (= pass.-miles per mile).
Density of the freight traffic:
Ton-kilometers per km., 961,578 (1,059,947 ton-mi. per mi.).
Work of the locomotives:
Kilometers per 1,000,000 ton-km. of freight, 6,650 km. (6037 mi. per 1,000,000 ton-mi.)
Average net weight of a freight train, 288 tons (317.5 short tons).
Number of locomotives, 19,820.
Number of passenger cars, 29,099.
Number of freight cars, 470,626.

cipal data relating to the year 1912, and which may be used to characterize, in a general way, the present condition of the Russian railways.

The figures of 1913, as one may perceive from the preliminary information, are still higher, for the traffic continued to increase with the economic development of the country. To be able to meet this intense increase of traffic, a series of improvements and measures had been undertaken with the purpose in view of developing the capacity of the system. In the last years more than 100,000,000 of rubles ($51,500,000) have been spent for double-tracking, enlarging stations, strengthening the roadbed and decreasing the grades. At the same time, the locomotives of older types are being replaced by powerful machines (Consolidation type), and the capacity of the cars has been raised up to 20 tons. The opening in the near future of a rather large number of lines now building, which will be mentioned further on, will also assist in relieving somewhat the intense work of the system now operating.

The average receipts of all the Russian railways per passenger- and ton-kilometer tend to decrease and are now figured almost as follows: At 0.8 copecks* per passenger-verst (0.75 cop. per passenger-km. = 0.62 cents per passenger-mile); to 1.35 cop. per ton-km. (1.02 cents per ton-mile) of slow freight and to 2.85 cop. per ton-km. (2.145 cents per ton-mile) of luggage and fast freight.

These average receipts resulted from the application of rather complicated tariffs, which are in Russia since 1889 under the strict control of the State, to which belongs exclusively the right to fix taxes collected by all the Russian railways.

The Russian tariffs belong to the system called "historic" (with more than 4500 classifications of merchandise) and differential; the taxes are collected per pood† and per full carload. The taxes for the first 200 versts (214 km. = 133 mi.) vary, according to the classification of the merchandise, from 1/8 to 1/45 copeck per pood-verst transported (7.16 to 1.27 copecks per ton-km. = 5.39 to 0.96 cents per ton mile), while for the distances for 200 to 300 versts they decrease even to 1/150 and

* 100 copeks = 1 ruble = 0.515 dollars.

† 1 metric ton = 61.05 pood; 1 short ton = 55.371 pood.

even 1/200 (0.39 to 0.29 copeck per ton-km. = 0.29 to 0.22 cent per ton-mile). There are special tariffs for coal, minerals, naphtha, salt, sugar, etc., as well as decreased tariffs for exportation.

The passenger tariff is calculated according to zones of from 25 to 70 versts,* with an initial tax of 1.5 cop. per verst (1.41 copeks per km. = 1.17 cents per mile) for the III class and an increase of 20, 25 and 40 cop. per zone. The third class ticket for a trip of 3010 versts (3221 km. = 1996 mi.) costs, as an illustration, 17.80 rubles ($9.18).

The taxes of the second and first classes are determined by multiplying the tax of the third class by 1.5 and 2.5 respectively.

There are additional amounts to be paid for express trains and for reserved seats.

The general tendency of the Russian state has been directed, until now, toward a systematic decrease in the tariffs. It is probable that, however, in the very nearest future they will have to resort to an increase of the principal taxes.

For the moment, all transportations by rail are still burdened with a rather heavy war tax.

Towards the end of 1914 there were in Russia some 16,800 km. (10,489 mi.) of lines under construction, of which 3800 km. (2361 mi.) are already being operated in a temporary manner. The last years can therefore be considered in a general way as the beginning of a new period of a great extension of the railway system in Russia. It is to be feared that the European war will retard, more or less, this development so necessary for the empire.

Two thirds of the Russian railways belong to the State. Towards the end of 1914 the total length of the system in operation was 76,975 km. (47,830 mi.), of which 51,615 km. (32,072 mi.) were the property of the State and only 25,360 km. (15,758 mi.) belonged to private companies.

This predominance of the government lines is due to the policy of buying out companies, which the Russian government carried out from 1881 to 1901, and to the construction by the government during that same period of a few main lines (the Trans-Siberian, Trans-Caspian, Tashkent). In 1890 the govern-

* 1 verst = 1.067 km.

ment system represented only 29 percent of the entire railway system, and in 1900 the government was in possession of 70 percent of the system. This proportion has been maintained almost the same until now, but it will decrease in the future, for, since 1908, the Russian government has granted a large number of lines to new companies (25 companies with a total capital of about 600,000,000 rubles ($309,000,000), while during the period 1881 to 1901, it hardly authorized any formation of new companies, granting new franchises only to existing companies. Thus were formed the seven great companies: ''Moscou-Kazan'', ''Moscou-Kiev-Voronège'', ''Caucasus'', ''Riazan-Ouralsk'', ''South East'', ''Moscou-Vindava-Rybinsk'', and ''Warsaw-Vienna''. This last company was bought back by the State in 1912; this purchase has been the only one since 1902.

It can be seen that the question of the nationalization of the railroads has been discussed many times in Russia and that there were long intervals during which the State régime prevailed.

At the present time, it seems that the creation of a series of new companies, on one hand, and the financial preoccupations which will fall upon the government after the European war, on the other hand, announce for Russia the beginning of an era rather prolonged, during which will prevail the régime of private companies under State control.

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2 The Hand Book of Tariffs (Ministry of Finances).

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NAME OF RAILWAY WITH ENUMERATION AND INDICATION OF LENGTH OF THEIR MAIN LINES	YEARS	AVERAGE KILOMETERS OPERATED	TOTAL OF TRAIN KILOMETERS (THOUSAND)	PASSENGERS CARRIED (THOUSAND)	TOTAL OF PASSENGERS KILOMETERS (MILLIONS)	TOTAL THOUSANDS TONS OF FREIGHT CARRIED	TOTAL OF FREIGHT TON KM. (MILLIONS)	AVERAGE FREIGHT TRAINLOAD (TONS)	GROSS RECEIFTS THOUSANDS OF RUBLES)	OPERATING EXPENSES (THOUSANDS OF RUBLES	RATIO OF OPER EXP TO GR REC %
A. STATE RAILWAYS											
1/ ALEXANDER LINE MOSCOW = BREST WITH BRANCHES	I907	I097	9063	3996	390	3094	677	I30	I7.33I	I3.743	79,3
	I908	I097	9008	449I	54I	3553	782	I56	I6.700	I3.I69	78,9
	I909	I097	9086	4402	505	3439	890	I86	I7.729	I2.835	72,4
	I9I0	I097	9069	4900	554	335I	888	I90	20.226	I3.068	64,6
	I9II	I097	9I90	5592	583	3345	846	200	I9.322	I2.I54	62,9
	I9I2	II02	9709	6I98	643	3608	927	200	2I.076	I3.I40	62,3
	I9I3	II50	9569	7078	75I	3978	I089	273	23 735	I4.296	60,2
2/ BASKOONCHAK LINE PORT OF VLADIMIR = BASKOONCHAK WITH BRANCHES	I907	73	89	I2	0,5	396	2I	256	508	335	66,0
	I908	73	I07	I8	0,7	470	25	233	58I	386	66,5
	I909	73	I03	I9	0,8	423	22	209	5I2	36I	70,4
	I9I0	73	II9	I9	0,8	522	26	220	626	386	6I,7
	I9II	73	I25	20	0,8	546	27	230	66I	369	55,9
	I9I2	73	I2I	22	0,9	5I8	26	226	63I	369	58,5
	I9I3	73	I26	2I	0,9	559	29	2I7	708	424	59,9
3) WARSAW = VIENNA LINES WARSAW = GRANITSA (308), SKERNEVITSI ALEXANDROV (161), WARSAW = KALISH (257) WITH BRANCHES	I907										
	I908										
	I909	SEE		PRIVATE	RAILWAY		N. B.				
	I9I0										
	I9II										
	I9I2	783	9.I30	II.668	6I8	I0.333	I.672	389	34.376	I9.073	55,5
	I9I3	800	9.364	I3.377	665	II.058	I.8I9	432	37.048	I9.8I7	53,5
4/ CATHERINE LINES YASSINOVATAYA = DOLINSKAYA (507), CHAPLINO = BERDIANSK (209), DEBALTSEVO = SVENEVO (156), DEBALTSEVO = MILLEROVO (188), DEBALTSEVO = KOOPIANSK (234), VERHOVTSEVO = DOLGHINTSEVO (120), ROSTOV = NIKITOVKA (243), DOLGINTSEVO = VOLNOVAHA (428), KARAVANNAYA = CHERNOUHINO (120) WITH NUMEROUS BRANCHES AND JUNCTIONS.	I907	2952	24.I76	4.870	467	22.392	4.589	256	54.57I	38.390	70,3
	I908	2956	24.II2	5.755	608	24.375	4.906	263	52.427	38.274	73,0
	I909	3003	23.479	6.539	70I	25.I30	5.383	298	58.06I	35.338	60,9
	I9I0	3003	2I.268	6.990	753	25.333	5.447	343	60.734	34.I74	55,4
	I9II	2993	22.5I3	7.642	827	27.892	5.826	363	65.576	34.04I	5I,9
	I9I2	2994	22.953	I0.394	979	30.60I	5.993	367	68.736	34.786	50,6
	I9I3	3002	25.I49	I2.I07	I040	34.607	6.882	384	78.498	39.240	50,0

NAME OF RAILWAY WITH ENUMERATION AND INDICATION OF LENGTH OF THEIR MAIN LINES	YEARS	AVERAGE KILOMETERS OPERATED	TOTAL OF TRAIN KILOMETERS (THOUSAND)	PASSENGERS CARRIED (THOUSAND)	TOTAL OF PASSENGERS KILOMETERS (MILLIONS)	TOTAL THOUSANDS TONS OF FREIGHT CARRIED	TOTAL OF FREIGHT TON KM. (MILLIONS)	AVERAGE FREIGHT TRAINLOAD (TONS)	GROSS RECEIPTS THOUSANDS OF RUBLES)	OPERATING EXPENSES (THOUSANDS OF RUBLES)	RATIO OF OPER EXP TO GR REC %
5/ TRANCAUCASIAN	1907	1639	9.646	8.528	428	2.957	751	163	29.518	22.464	76,1
LINES: POTI = BAKU (899), SAMTREDI = BATUM (105), RION = TKWIBULI (52), TIFLIS = KARS (297), ALEXANDROPOL = ERIVAN (155), SHAROPAN = CHIATURI (53), ULUHANLU = DJULFA (190) WITH BRANCHES	1908	1830	10.978	8.985	477	4.273	1.164	169	27.091	22.805	84,2
	1909	1830	10.204	8.640	490	4.208	1.174	188	28.656	21.384	74,6
	1910	1830	10.356	8.828	534	4.372	1.184	197	28.555	20.668	71,4
	1911	1830	10.465	9.224	607	3.537	1.038	208	29.604	19.586	66,2
	1912	1830	11.215	10.052	667	4.148	1.155	214	32.288	19.840	61,2
	1913	1835	12.121	12.004	783	4.665	1.258	216	35.515	22.430	63,2
6/ LIBAVA = ROMNI	1907	1357	8.132	2.546	281	4.269	1.231	265	20.979	12.122	57,8
LINES: LIBAVA = KOSHEDARI (317), NOVOVILEYSK = ROMNI (762), OSSIPOVICHI = OORECHIE (72), KALKOONI = RADSIVILISHKI (199) WITH BRANCHES	1908	1350	8.190	2.774	288	4.840	1.312	269	18.008	11.951	66,4
	1909	1350	8.359	2.891	295	5.517	1.485	292	19.925	12.054	60,5
	1910	1350	8.258	3.419	362	5.475	1.492	298	21.099	11.856	54,6
	1911	1368	8.881	4.007	414	5.696	1.593	309	22.901	11.280	49,3
	1912	1410	8.864	4.307	438	5.632	1.564	315	24.058	11.703	48,6
	1913	1422	8.660	4.986	532	5.959	1.575	351	23.988	13.742	57,3
7/ MOSKOW = KOORSK = NIJNI NOVGOROD AND MOOROM	1907	1217	14.680	7.655	559	8.575	1.848	211	33.026	24.133	73,1
LINES: MOSCOW = NIJNI = NOVGOROD (440), KOVROV = MOOROM (110), MOSCOW = KOORSK (540) WITH BRANCHES	1908	1207	14.980	9.183	634	9.351	1.939	200	32.193	23.271	72,3
	1909	1207	13.696	9.570	651	7.551	1.709	220	31.938	21.041	65,9
	1910	1207	13.268	10.844	716	7.441	1.658	217	33.153	20.516	61,9
	1911	1209	13.117	12.843	865	7.494	1.734	274	35.491	19.732	55,6
	1912	1218	13.883	14.137	966	7.641	1.769	287	36.973	20.457	55,3
	1913	1232	14.640	15.244	1005	8.219	1.961	289	38.366	23.766	61,9
8/ NICOLAS	1907	1969	16.426	6.921	873	6.069	1.576	228	40.439	29.461	72,9
LINES: PETROGRAD = MOSCOW (652), LIHOSLAVL = VIASMA (258), BOLOGOYE = POLOTSK (476), MOSCOW CIRCULAR (53) WITH BRANCHES	1908	1982	17.870	7.939	983	8.342	2.137	262	39.888	30.863	77,6
	1909	1982	17.334	8.269	1010	8.927	2.303	287	41.920	31.953	76,2
	1910	1491	16.371	9.266	1135	10.069	2.350	314	44.649	30.433	68,1
	1911	1618	15.588	10.321	1235	10.078	2.117	325	44.104	26.745	60,6
	1912	1629	16.259	11.759	1287	11.532	2.274	367	49.197	28.555	58,0
	1913	1631	17.215	13.496	1492	12.978	2.260	364	51.152	31.545	61,7

NAME OF RAILWAY WITH ENUMERATION AND INDICATION OF LENGTH OF THEIR MAIN LINES	YEARS	AVERAGE KILOMETERS OPERATED	TOTAL OF TRAIN KILOMETERS (THOUSAND)	PASSENGERS CARRIED (THOUSAND)	TOTAL OF PASSENGERS KILOMETERS (MILLIONS)	TOTAL THOUSANDS TONS OF FREIGHT CARRIED	TOTAL OF FREIGHT TON KM. (MILLIONS)	AVERAGE FREIGHT TRAINLOAD (TONS)	GROSS RECEIPTS THOUSANDS OF RUBLES	OPERATING EXPENSES (THOUSANDS OF RUBLES)	RATIO OF OPER EXP TO GR REC
9/ PERM LINES: PERM = EKATERINBURG (499), EKATERINBURG TOORA (330), EKATERINBURG = CHELIABINSK (241), CHOOSSOVAYA = SSOLEVARNI (209), PERM = VIATKA (479), VIATKA = KOTLAS (385), PERM = KOONGOR = EKATERINBURG (380) WITH BRANCHES	1907	2218	9.398	2.678	450	2.413	1.013	175	16.990	11.853	69,8
	1908	2218	11.770	2.890	527	3.582	1.440	175	19.710	14.040	71,3
	1909	2271	12.626	3.171	509	3.718	1.511	170	20.611	14.620	71,0
	1910	2651	11.342	3.846	531	3.874	1.382	186	20.523	14.521	70,6
	1911	2651	11.938	4.244	609	3.397	1.362	191	21.392	13.407	62,7
	1912	2721	12.458	4.594	650	4.222	1.637	233	24.545	14.281	58,2
	1913	2732	13.308	4.916	689	4.739	2.037	261	29.196	15.588	53,4
10/ POLESSKIA LINES: VILNA = SSARNI (412), BELOSTOK = BARANOVICHI (217), BREST = TABINKA = BRIANSK (779), POLOTSK = VOLKOVISK (425, MOSTI = GROONO (56) WITH BRANCHES	1907	1445	6.907	1.615	249	2.416	732	164	13.293	9.616	72,3
	1908	1480	7.394	1.943	341	3.486	791	199	14.521	9.941	68,6
	1909	1480	7.865	2.054	298	4.029	1017	220	14.813	10.177	68,5
	1910	1975	7,704	2.549	377	3.871	964	229	15.052	10.923	72,5
	1911	2008	9.096	3.206	481	3.878	1.088	216	16.682	11.719	70,3
	1912	2043	9.499	3.860	598	4.122	1.101	224	18.043	12.362	68,5
	1913	2042	9.734	4.432	637	4.599	1.320	259	19.712	13.562	70,3
11/ PRIVISLINSKIA LINES: WARSAW = BREST (217), MLAVA = KOVEL (458), IVANGOROD = LOOKOV (60), SKARJISKO = KOLOOSHKI (114), IVANGOROD = DOMBROVA (302), SSEDLETS = MALKIN (55), BREST = HOLM (112), LAPI = MALKIN (140) OSTROLENKO = PILVA (129), LOOKOV = LOOBLIN (110), SSEDLETS = VOLKOVISK (196) KOVEL = GRAYEVO (344), BIELSK = BELOVESH (48) WITH BRANCHES	1907	2303	14.511	6.019	438	8.090	1.953	208	28.886	24.163	83,6
	1908	2421	16.478	7.511	630	9.179	2.275	213	31.923	27.970	87,2
	1909	2421	16.264	8.037	668	9.776	2.441	232	33.298	26.275	79,3
	1910	2421	15.943	9.431	825	9.697	2.421	234	36.915	25.604	69,5
	1911	2434	17.338	10.912	856	10.467	2.805	316	40.336	23.329	57,8
	1912	2445	18.220	12.376	897	11.738	3.028	296	44.103	24.509	55,6
	1913	2445	17.808	14.390	1080	11.871	3.212	308	44.342	26.347	59,4
12/ RIGA = OREL LINES: RIGA = OREL (1004), LASSENHOF = TUKKUM (58) WITEBSK = SHLOBIN (281), TORENSBERG MOORAVIEVO (133) WITH BRANCHES	1907	1562	9.187	7.316	402	4.849	1.020	206	23.637	14.612	61,8
	1908	1562	9.791	8.481	457	5.574	1.253	219	22.513	14.593	64,6
	1909	1562	10.636	8.448	462	6.632	1.527	238	24.975	14.614	58,7
	1910	1562	11.235	9.399	505	7.237	1.794	262	27.895	15.032	53,9
	1911	1562	10.932	10.502	555	7.112	1.574	266	27.745	14.288	50,0
	1912	1562	11.154	11.661	621	7.498	1.650	280	29.905	14.954	50,0
	1913	1562	11.425	12.913	663	8.413	1.750	298	31.538	17.890	56,7

NAME OF RAILWAY WITH ENUMERATION AND INDICATION OF LENGTH WITH THEIR MAIN LINES	YEARS	AVERAGE KILOMETERS OPERATED	TOTAL OF TRAIN KILOMETERS (THOUSAND)	PASSENGERS CARRIED (THOUSAND)	TOTAL OF PASSENGERS KILOMETERS (MILLIONS)	TOTAL THOUSANDS TONS OF FREIGHT CARRIED	TOTAL OF FREIGHT TON KM. (MILLIONS)	AVERAGE FREIGHT TRAINLOAD (TONS)	GROSS RECEIPTS THOUSANDS OF RUBLES	OPERATING EXPENSES (THOUSANDS OF RUBLES)	RATIO OF OPER EXP TO GR REC %
13/ SSAMARA = SLATOUST	1907	1306	13.696	1.578	1.405	2.711	1.518	116	25.131	26.940	103,5
LINES: BATRAKI = CHELIABINSK (1130), BERDIAOOSH = BAKAL (52), KROTOVKA = SSOORGOOT (86) WITH BRANCHES	1908	1306	13.803	2.156	1.246	3.843	1.656	157	24.200	23.653	97,6
	1909	1306	14.445	2.753	1.281	4.683	1.754	165	25.851	22.335	86,5
	1910	1306	12.947	3.239	1.277	4.804	1.677	187	26.012	20.855	80,0
	1911	1306	12.250	2.977	999	4.132	1.680	218	23.719	17.022	71,8
	1912	1306	13.871	3.211	1.117	4.820	2.026	237	27.537	17.606	63,9
	1913	1306	13.186	3.756	1.126	5.157	1.932	241	28.168	19.053	67,6
14/ SSISRAN = VIASMA	1907	1400	10.272	2.311	528	3.004	708	134	14.850	18.042	121,8
LINES: VIASMA = BATRAKI (1158) AND OOSLOVAYA = YELETS (194) WITH BRANCHES	1908	1400	10.807	2.798	682	3.931	950	142	15.376	16.782	109,0
	1909	1400	11.128	3.215	644	4.157	1.181	174	16.786	15.655	93,4
	1910	1400	10.165	3.499	561	4.134	975	172	16.027	14.971	94,0
	1911	1400	9.629	3.525	536	3.703	899	189	16.082	12.360	76,8
	1912	1400	9.392	3.663	564	4.027	974	212	17.284	12.475	72,2
	1913	1408	9.564	4.364	644	4.276	1.009	220	18.394	14.448	78,5
15/ NORTHERN	1907	3152	11.877	7.718	562	4.236	931	160 86	25.045	18.488	74,3
LINES: MOSCOW = YAROSLAVL (280), ALEXANDROV = IVANOVO (204), YAROSLAVL = KOSTROMA (91), OOROCH = VOLOGDA (204), VOLOGDA = ARHANGHELSK (636), NOVKI = KINESHMA (182), NEREHTA = YERMOLINO (65), YAROSLAVL = RISINSK (80), MOSCOW = SSAVELOVO (129), VOLOGDA = VIATKA (636), OBOOHOVO = VOLOGDA (589) WITH BRANCHES	1908	3137	13.375	8.774	784	5.260	1.174	185 121	26.946	20.541	76,3
	1909	3137	12.947	9.032	772	5.317	1.286	208 111	29.066	20.020	69,2
	1910	3137	12.840	9.636	830	5.615	1.357	225 117	32.627	19.682	60,3
	1911	3148	13.483	10.744	874	5.651	1.452	236 117	33.984	19.081	56,1
	1912	3148	14.408	12.550	1.015	6.284	1.822	286 137	38.812	20.963	54,0
	1913	3216	15.857	14.481	1.344	6.746	2.074	287 149	42.996	24.498	57,0
16/ NORTH WESTERN	1907	2693	21.186	14.010	1.029	5.191	1.060	123	34.766	29.633	85,2
LINES: PETROGRAD = ORANIENBAUM (75), BALTIC PORT = TOSNA (415), TAPS = YOORYET (113), PSKOV = RIGA (303), VALK = YOORYEV (83), KEGEL = KAPSAL (81), PETROGRAD = WARSAW (1118), LANDVAROVO VERJBOLOVO (173), ORANI = GRODNO (242), PITALOVO = SSITA (67) WITH BRANCHES	1908	2724	22.684	15.609	1.241	6.673	1.267	131	37.536	29.736	79,2
	1909	2724	22.149	17.040	1.301	6.527	1.303	144	38.835	29.299	75,6
	1910	2724	20.972	19.331	1.443	6.693	1.398	169	42.345	28.515	67,0
	1911	2724	20.823	22,508	1.446	7.075	1.495	193	44.113	26.949	61,1
	1912	2704	21.717	24.586	1.671	8.145	1.742	217	49.047	28.709	58,5
	1913	2710	23.159	27.012	1.803	9.485	1.986	239	53.445	32.242	60,3

NAME OF RAILWAY WITH ENUMERATION AND INDICATION OF LENGTH OF THEIR MAIN LINES	YEARS	AVERAGE KILOMETERS OPERATED	TOTAL OF TRAIN KILOMETERS (THOUSAND)	PASSENGERS CARRIED (THOUSAND)	TOTAL OF PASSENGERS KILOMETERS (MILLIONS)	TOTAL THOUSANDS TONS OF FREIGHT CARRIED	TOTAL OF FREIGHT TON KM. (MILLIONS)	AVERAGE FREIGHT TRAINLOAD (TONS)	GROSS RECEIPTS THOUSANDS OF RUBLES	OPERATING EXPENSES (THOUSANDS OF RUBLES)	RATIO OF OPER EXP TO GR REC %
17/ SOUTH = WESTERN LINES: ODESSA = KOVEL (867), RASDELNAYA = OONGHENI (225), BIRSOOLA = SNAMENKA (334), SLOBODKA = NOVOSELITSI (402), VAPNIARKA = TSVIETKOVO (268), SHMERINKA = VOLOCHISK (166), KASATIN KIEV (163), SDOLBUNOVO = RADSIVILOVO (94), BENDERI = RENI (289), SHMERINKA = OKNITSA (111), KASATIN = OOMAN (193), FASTOV = SNAMENKA (300), KIEV = KOVEL (446), ROVNO SSARNI (97) WITH BRANCHES	1907	4293	33.598	10.954	1.254	11.582	4.006	210	72.105	45.757	63,5
	1908	4180	30.495	11.663	1.441	13.235	4.158	214	64.565	44.397	68,9
	1909	4180	28.997	12.117	1.405	13.654	4.195	232	68.596	44.552	65,1
	1910	4180	28.783	13.069	1.559	15.027	4.469	250	73.829	44.023	59,7
	1911	4193	31.360	14.613	1.772	15.108	4.683	281	84.938	43.816	51,6
	1912	4189	31.895	15.810	1.903	13.782	4.656	282	83.301	43.725	52,5
	1913	4182	32.347	17.167	2.076	15.089	4.742	293	88.016	45.580	51,8
18/ SOUTH LINES: KOORSK = SEVASTOPOL (1000), LOSOVAYA = NIKITOVKA (180), KRAMATORSKAYA = POPASNAYA (82), BELGOROD = KOOPIANSK (155), DJANKOY=FEODOSSIA (120), VLADISLAV= OVKA = KERTCH (91) HARKOV = SNAMENKA = NICOLAEV (592), LOOBOTIN = VOROJBA (226), KREMENCHOOG = ROMNI (213), POLTAVA = LOSOVAYA (175), KORISTOVKA = PIATIHATKI (72), NICOLAEV = HRSON (63) WITH BRANCHES	1907	3277	28.676	8.883	941	17.980	5.657	214	59.079	38.852	65,8
	1908	3277	28.569	10.243	1.153	18.726	4.402	226	57.314	39.369	68,6
	1909	3277	26.536	12.376	1.306	19.853	4.637	268	66.099	39.128	59,3
	1910	3277	24.396	13.826	1.466	21.474	4.603	299	68.256	38.047	55,0
	1911	3277	25.320	15.226	1.655	22.744	4.598	324	72.002	35.810	49,7
	1912	3282	23.808	16.682	1.810	24.356	4.124	337	67.846	37.060	54,6
	1913	3283	24.875	18.449	1.983	26.797	4.472	365	72.712	40.240	55,4
19/ TRANSBAYKAL LINE: TNNOKENTIEVSKAYA = IRKOOTSK = MANDJOORIA AND SRETENSK (1806) WITH BRANCHES	1907	1805	8.346	876	369	688	461	119	11.162	26.575	238,1
	1908	1815	7.918	2.061	615	1.268	482	103	9.175	23.202	252,8
	1909	1815	6.741	1.866	575	1.384	535	151	11.095	20.788	187,4
	1910	1815	6.741	1.869	622	1.219	528	156	11.498	20.684	179,6
	1911	1822	7.561	2.200	500	851	475	182	10.897	17.995	165,1
	1912	1821	9.420	2.760	749	1.019	600	191	13.050	19.388	148,6
	1913	1821	8.872	3.143	818	1.066	594	207	13.732	19.875	144,8
20/ OMSK + LINES: TIUMEN = KULOMSINO (569), LSINARSKAYA = SHADRINSK (118), EKATERINBURG = TIUMEN (325), BOGDANOVICH = SSINARSKAYA (40) EKATERINBURG = TCHELIABINSK (241) NOVONI = KOLAEVSK = TCHELIABINSK (1425) WITH BRANCHES NEWLY FORMED OF SECTIONS OF SIBERIAN AND PERM RYS AND OF SOME NEW LINES	1913	687	367	81	12	12	41	281	514	699	136,0

NAME OF RAILWAY WITH ENUMERATION AND INDICATION OF LENGTH OF THEIR MAIN LINES	YEARS	AVERAGE KILOMETERS OPERATED	TOTAL OF TRAIN KILOMETERS (THOUSAND)	PASSENGERS CARRIED (THOUSAND)	TOTAL OF PASSENGERS KILOMETERS (MILLIONS)	TOTAL THOUSANDS TONS OF FREIGHT CARRIED	TOTAL OF FREIGHT TON KM. (MILLIONS)	AVERAGE FREIGHT TRAINLOAD (TONS)	GROSS RECEIPTS THOUSANDS OF RUBLES)	OPERATING EXPENSES (THOUSANDS OF RUBLES)	RATIO OF OPER EXP TO GR REC %
21/ SIBERIAN	1907	3365	25.038	1.827	1.368	2.460	1.740	186	39.540	41.566	105,1
LINE: TCHELIABINSK = TNNOKENTIEVSKAYA WITH BRANCHES	1908	3350	27.820	2.782	2.089	4.554	3.075	175	41.842	39.014	93,2
	1909	3350	25.145	3.665	2.332	4.642	2.675	181	39.967	36.527	88,9
	1910	3350	24.396	3.466	2.157	5.043	2.935	163	39.753	33.698	84,8
	1911	3365	25.386	3.393	1.866	3.838	2.451	250	37.953	30.655	80,8
	1912	3370	27.991	3.794	2.313	3.758	3.058	270	46.956	33.560	71,5
	1913	3384	25.436	4.262	2.173	3.679	2.874	312	46.162	32.748	70,9
22/ CENTRAL ASIATIC	1907	2539	8.218	1.874	250	1.004	646	163	15.788	16.933	107,3
LINES: KRASNOVODSK = TASHKENT (1869), CHERNIAYEVO=AUDIJAN (326), MERV = KOOSHKA (315) WITH BRANCHES	1908	2527	9.363	2.715	361	1.514	856	161	15.385	17.372	112,9
	1909	2527	9.609	2.986	382	1.492	856	182	16.127	16.880	104,7
	1910	2527	10.336	3.432	451	2.118	1.080	197	19.248	17.007	88,4
	1911	2527	10.790	3.933	527	1.826	1.028	219	21.710	15.442	71,1
	1912	2527	10.461	4.250	578	1.817	1.026	227	21.335	15.253	71,5
	1913	2527	9.876	4.558	569	1.744	851	232	19.115	16.427	85,9
23/ TASHKENT	1907	2242	8.346	1.001	273	1.084	837	145	16.509	17.735	107,4
LINE: KINEL = TASHKENT WITH BRANCHES	1908	2236	9.737	1.373	438	1.910	1.298	196	18.155	18.637	102,6
	1909	2236	11.128	1.647	491	2.292	1.436	201	19.521	17.437	89,3
	1910	2236	12.626	1.463	510	2.534	2.123	238	25.506	18.744	73,4
	1911	2236	13.733	1.496	567	1.814	1.777	234	26.913	16.700	69,5
	1912	2236	12.718	1.658	593	2.087	1.892	286	27.259	17.299	63,5
	1913	2236	12.869	1.992	658	2.376	1.951	307	28.810	19.251	66,8
TOTALS FOR STATE RAILWAYS	1907	43.904	291.668	103.188	12.517	115.460	32.975	201	593.153	481.413	81,2
	1908	44.128	305.249	120.144	15.547	137.939	37.341	206	586.049	479.966	81,9
	1909	44.228	298.477	128.737	16.079	143.351	39.320	219	624.383	463.273	74,2
	1910	44.612	289.135	130.412	17.169	149.903	40.752	239	664.528	453.407	68,2
	1911	44.841	299.518	159.126	17.775	150.184	40.548	263 117	696.125	422.480	60,7
	1912	45.791	319.146	189.992	20.678	171.688	44.716	280 137	776.359	460.067	59,3
	1913	46.687	325.527	214.230	22.544	188.067	47.718	304 149	825.862	503.707	61,0

NAME OF RAILWAY WITH ENUMERATION AND INDICATION OF LENGTH OF THEIR MAIN LINES	YEARS	AVERAGE KILOMETERS OPERATED	TOTAL OF TRAIN KILOMETERS (THOUSAND)	PASSENGERS CARRIED (THOUSAND)	TOTAL OF PASSENGERS KILOMETERS (MILLIONS)	TOTAL THOUSANDS TONS OF FREIGHT CARRIED	TOTAL OF FREIGHT TON KM. (MILLIONS)	AVERAGE FREIGHT TRAINLOAD (TONS)	GROSS RECEIPTS THOUSANDS OF RUBLES	OPERATING EXPENSES (THOUSANDS OF RUBLES)	RATIO OF OPER EXP TO GR REC %
B. PRIVATE RAILWAYS											
1/ BOGOSLOVSK	I907	2I7	247	206	I7	300	28	I02	906	646	7I,3
LINE: GOROGLAGODATSKAYA = NADEJDINSKI SAVOD WITH BRANCHES	I908	2I7	336	2I5	I9	406	47	I93	86I	497	57,7
	I909	2I7	340	206	I9	470	52	203	898	537	59,8
	I9I0	2I7	373	209	I7	534	62	223	I.038	560	53,9
	I9II	2I7	486	243	20	608	75	204	I.I86	542	45,7
	I9I2	2I7	5I4	285	25	727	80	209	I.346	588	43,7
	I9I3	2I7	546	346	30	793	85	2I7	I.593	688	43,2
2/ BELGOROD = SSOOMI	I907	I57	3I6	II7	5	527	56	22I	77I	506	65,6
LINE: BASSI = BELGOROD WITH BRANCHES	I908	I57	264	I25	6	426	4I	230	6I5	500	8I,2
	I909	I57	3I0	I38	7	532	55	237	757	537	70,8
	I9I0	I57	328	I44	7	627	6I	245	878	568	64,3
	I9II	I57	38I	208	I3	628	62	235	945	646	68,3
	I9I2	I57	366	228	I3	489	37	20I	80I	568	70,8
	I9I3	I57	354	235	I3	543	42	24I	797	542	68,I
3/ WARSAW = VIENNA	I907	76I	8.367	6.859	384	7.I48	I.057	266	23.886	I9.496	8I,6
(VID "STATE RYS", № 3)	I908	76I	8.742	7.803	446	7.260	I.I39	279	25.234	I9.743	78,5
	I909	76I	8.785	8.586	5I5	7.604	I.I83	286	28.444	20.068	70,6
	I9I0	76I	8.763	9.633	584	8.300	I.3I5	322	3I.I46	20.227	65,0
	I9II	766	9.I89	I0.736	6II	9.294	I.456	34I	33.528	2I.899	65,3
	FROM 1912 = = = - = = STATE'S OWNERSHIP										
4/ VLADICAVCAS	I907	2496	I8.832	4.3I9	645	4.953	2.4II	226	42.558	26.307	6I,8
LINES: ROSTOV = VLADICAVCAS (698), BESLAN = BALADJARI (628), TIHORETSKAYA = TSARITSIN (535), KAVKASKAYA = STAVROPOL (154), KAVKASKAYA = TEKATERINOVAR (135), TIHORETSKAYA = NOVOROLLISK (272) WITH BRANCHES	I908	2496	I9.58I	5.I08	875	4.988	2.390	204	4I.993	25.283	60,2
	I909	2496	20.223	6.3I3	962	5.9I2	2.668	2I9	49.950	28.3I7	56,6
	I9I0	2496	I9.795	7.58I	I.093	6.247	2.8II	246	52.46I	27.608	52,6
	I9II	2509	2I.I66	8.29I	I.I83	6.956	3.005	286	55.I37	28.34I	5I,4
	I9I2	2529	2I.973	8.970	I.I84	6.9I3	3.I3I	295	57.233	30.I56	52,7
	I9I3	2535	24.0I9	9.75I	I.36I	8.289	3.829	309	68.295	35.I96	5I,5

NAME OF RAILWAY WITH ENUMERATION AND INDICATION OF LENGTH OF THEIR MAIN LINES	YEAR	AVERAGE KILOMETERS OPERATED	TOTAL OF TRAIN KILOMETERS (THOUSAND)	PASSENGERS CARRIED (THOUSAND)	TOTAL OF PASSENGERS KILOMETERS (MILLIONS)	TOTAL THOUSANDS TONS OF FREIGHT CARRIED	TOTAL OF FREIGHT TON KM. (MILLIONS)	AVERAGE FREIGHT TRAINLOAD (TONS)	GROSS RECEIPTS THOUSANDS OF RUBLES)	OPERATING EXPENSES (THOUSANDS OF RUBLES)	RATIO OF OPER EXP TO GR REC %
5/ VOLGA = BOOGOOLMA	I9II	I86	I86	70	5	I26	I2	I27	403	458	II3,8
LINE: MELEKESS = TCHISHMA = BOOGOOLMA WITH BRANCHES	I9I2	364	366	I27	I5	I8I	27	I43	827	778	94,0
	I9I3	364	402	I47	I7	203	3I	I8I	I049	I029	99,0
6/ HERBI = KELTSI	I9II	I39	40I	408	I6	57I	45	248	986	672	68,I
LINE: HERBI = KELTSI WITH BRANCHES	I9I2	I39	534	532	23	985	88	3I3	I565	II06	70,7
	I9I3	I42	536	630	27	I059	93	3I0	I729	II48	66,4
7/ EISK	I9II	I42	I27	I07	7	I3I	I0	242	37I	2II	56,9
LINE: SSOSSIKA = EISK	I9I2	I42	269	257	20	266	24	284	840	556	66,2
	I9I3	I42	292	266	2I	346	4I	304	I272	694	54,6
8/ LODS	I907	79	322	I275	30	I55I	47	237	I908	I546	8I,I
LINES: LODS = SLOTVINI, LODS = KOLOOSHKI, LODS = VIDSEV WITH BRANCHES	I908	79	349	I4I7	33	I687	52	249	2I68	I666	76,8
	I909	79	369	I504	36	2003	59	246	2373	I637	68,8
	I9I0	79	358	I597	38	2070	6I	240	2572	I640	63,8
	I9II	79	389	I830	43	2I98	66	255	2727	2705	62,5
	I9I2	79	396	I72I	4I	2069	62	249	2603	I7I7	66,0
	I9I3	79	406	I763	42	2096	62	25I	2602	I6I9	62,2
9/ MOSCOW = VINDAVA = RIBINSK	I907	2624	9.202	5.I82	474	3.276	926	2I0	20.798	I3.870	66,7
LINES: RIBINSK = PSKOV (656), TCHOODOVO = STARAYA ROOSA (168), PETROGRAD = VITEBSK (571), MOSCOW = VINDAVA (1099) WITH BRANCHES	I908	2636	9.748	5.552	522	3.866	I.I04	242	22.529	I3.960	6I,5
	I909	2636	I0.6I4	5.807	530	4.636	I.667	295	27.352	I5.I36	55,3
	I9I0	2636	I0.786	6.838	607	4.752	I.792	309	28.939	I5.I73	52,3
	I9II	2636	I0.634	7.520	665	5.038	I.737	340	29.I86	I4.54I	49,8
	I9I2	2636	II.II5	8.259	7I4	5.624	I.838	345	3I.43I	I5.02I	47,8
	I9I3	2636	II.293	9.I0I	7I4	6.3I8	2.007	379	33.806	I6.537	48,9

NAME OF RAILWAYS WITH ENUMERATION AND INDICATION OF LENGTH OF THEIR MAIN LINES	YEARS	AVERAGE KM. OPERATED	TOTAL OF TRAIN KM. (THOUSANDS)	PASSENGERS CARRIED (THOUSANDS)	TOTAL OF PASSENGER KM. (MILLIONS)	TOTAL THOUSANDS TONS OF FREIGHT CARRIED	TOTAL OF FREIGHT TON KM. (MILLIONS)	AVERAGE FREIGHT TRAINLOAD (TONS)	GROSS RECEIPTS (THOUSANDS OF RUBLES)	OPERATING EXPENSES (THOUSANDS OF RUBLES)	RATIO OF OPER EXP TO GR REC %
10/ MOSCOW KASAN	1907	2215	10.700	5.025	532	5.238	1.401	243	28.201	23.952	84,9
LINES: MOSCOW = RIASAN (198), RIASAN=SVIASHSK (802) TIMIRIASEVO = NIJNI NOVGOROD (304), KOOSTAREV=KA = SEMETCHINO (102), ROOSAYEVKA = SSISRAN = BATRAKI (316), ROOSAYEVKA = PENSA (140), INSA=SSIMBIRZK (166), LOOBERTSI = ARSAMASS (397) WITH BRANCHES	1908	2215	11.877	5.607	629	5.338	1.536	222	28.720	21.181	73,5
	1909	2215	12.626	5.972	639	5.541	2.067	253	33.570	21.487	64,0
	1910	2215	12.412	6.489	705	5.844	2.144	270	35.732	20.777	58,2
	1911	2215	11.991	7.037	735	5.759	1.821	287	35.409	20.210	57,0
	1912	2298	12.808	7.671	804	6.402	1.974	303	36.925	20.627	56,5
	1913	2610	14.304	8.582	920	7.204	2.382	340	43.057	24.711	57,4
11/ MOSCOW = KIEV = VORONESH	1907	2623	13.696	4.093	530	7.107	1.579	202	31.073	21.232	68,3
LINES: MOSCOW = ARTAKOVO (807), KIEV = TCHERNICOV (261), KROOTI = KRASNOYE (219), KIEV = POLTAVA (352), NAVLA = KONOTOP (193), VOROSHBA HOOTOR MIHAYLOVCKI (134), MARMIJI = VERHOVIE (131) WITH BRANCHES	1908	2651	14.017	4.401	551	7.459	1.730	205	31.357	21.224	67,9
	1909	2651	14.445	4.875	694	8.254	1.911	214	32.941	21.425	65,1
	1910	2651	14,124	5.761	796	8.698	1.939	225	37.354	21.060	56,5
	1911	2651	14.945	6.234	860	9.887	2.150	245	40.700	21.656	53,2
	1912	2663	16.247	6.667	864	11.109	2.488	260	45.018	23.289	51,7
	1913	2700	16.353	7.167	912	11.703	2.616	288	48.517	26.186	54,0
12/ RIASAN = OORALSK	1907	4367	18.190	4.639	604	684	1.985	191	37.732	37.509	99,4
LINES: RIASAN = KOSLOV (625), KOSLOV = SSARATOV (977), BOGOYAVLENSK = YELETS (235), MOSCOV= PAVLLETS (608, KASHIRA = VENEV (68), DANKOV SMOLENSK (683), BOGOYAVLENSK = SOSNOVKA (92) TAMBOV = KAMISHIN (589), RTISHTSHEVO = PENSA (210), RTISHTSHEVO = TAVOLJANKA (121, ATKARSK VULSK (278), POKROWSK SLOBODI = YERSHOV (233), KRASNI KUT = ASTRAHAN (613), YERSHAV OORALSK = NIKOLA = YEWSK (380), KRASNI KUT = ALEXANDROV GAY (162), WITH BRANCHES	1908	4367	18.618	5.286	786	8.259	2.460	199	38.982	35.432	90,6
	1909	4367	20.223	5.685	796	8.691	2.820	199	45.100	35.304	78,5
	1910	4367	21.935	5.952	900	9.726	3.221	206	52.096	37.601	72,3
	1911	4406	19.996	6.142	920	8.479	2.702	223	47.606	31.303	65,8
	1912	4406	20.817	6.378	914	9.215	2.853	225	50.510	31.944	63,2
	1913	4412	22,327	7.123	1.004	10.333	3.291	231	55.860	35.579	63,7
13/ NORTH DONETZ	1911	207	1.008	201	14	1.115	303	455	2.944	1.428	48,5
LINES: LGOV = HARKOW = RODAKOWO AND LINIAN = KRAMATORSKAYA = NIKITOVKA WITH BRANCHES	1912	653	4.284	882	76	5.512	1.429	473	13.515	5.624	41,6
	1913	679	4.812	1.077	101	6.674	1.665	495	16.024	6.300	39,3
14/ TROITSK	1912	109	27	19	2	31	3	151	161	71	43,9
LINES: POLETAYEVO = TROITSK	1913	109	119	86	8	198	21	198	819	347	42,4

NAME OF RAILWAY WITH ENUMERATION AND INDICATION OF LENGTH OF THEIR MAIN LINES	YEARS	AVERAGE KILOMETERS OPERATED	TOTAL OF TRAIN KILOMETERS (THOUSAND)	PASSENGERS CARRIED (THOUSAND)	TOTAL OF PASSENGERS KILOMETERS (MILLIONS)	TOTAL THOUSANDS TONS OF FREIGHT CARRIED	TOTAL OF FREIGHT TON KM. (MILLIONS)	AVERAGE FREIGHT TRAINLOAD (TONS)	GROSS RECEIPTS THOUSANDS OF RUBLES)	OPERATING EXPENSES (THOUSANDS OF RUBLES)	RATIO OF OPER EXP TO GR REC
15/ FERGANA LINE: KOKAND = NAMANGAN	I9I3	92	I08	2I2	I3	I3I	I0	I06	9I3	420	46,I
16/ SOUTH = EASTERN LINES: OREL = GRIASI = TSARITSIN (914), KOSLOV = ROSTOV (825), HARKOV = BALASHOV (677), YELETS = VALOOIKI (418), EAST DONETZ LINES (322) WITH BRANCHES	I907	3480	I8.5II	4.923	772	8.590	2.566	227	42.307	28.589	67,6
	I908	3480	I9.474	5.357	9I6	9.473	2.8II	224	44.497	30.969	69,8
	I909	3480	20.544	5.892	I.058	I0.206	3.I90	235	50.940	3I.I65	6I,3
	I9I0	3480	20.544	6.87I	I.I88	I0.074	3.I03	238	55.250	30.64I	55,4
	I9II	3480	20.404	6.884	I.I98	I0.485	3.200	252	55.I63	29.9I7	54,2
	I9I2	3480	2I.372	7.II8	I.203	II.052	3.474	265	55.809	30.360	54,4
	I9I3	3480	23.886	7.80I	I.328	I2.737	4.090	276	62.324	34.094	54,7
TOTALS FOR PRIVATE RAILWAYS	I907	I9.0I9	98.383	36.638	3.993	39.374	I2.056	22I	230.I40	I73.653	75,5
	I908	I9.059	I03.006	40.87I	4.783	49.I62	I3.3I0	2I4	236.956	I70.455	7I,9
	I909	I9.059	I08.479	44.978	5.256	53.849	I5.672	227	272.325	I75.6I3	64,5
	I9I0	I9.059	I09.4I8	5I.075	5.935	56.872	I6.509	24I	297.466	I75.855	59,I
	I9II	I9.790	III.303	55.9II	6.290	6I.275	I6.644	270	306.29I	I73.529	54,9
	I9I2	I9.872	III.088	49.II4	5.9I8	60.575	I7.508	282	298.584	I62.405	54,4
	I9I3	20.354	II9.757	54.287	6.5II	68.627	20.265	299	338.657	I85.090	54,6
TOTALS FOR ALL ABOVE NAMED RAILWAYS.	I907	62.923	390.05I	I39.826	I6.5I0	I54.834	45.03I	209	823.293	655.066	79,5
	I908	63.I87	408.255	I6I.0I5	20.330	I87.I0I	50.65I	200	823.005	650.42I	79,0
	I909	63.287	406.956	I73.7I5	2I.335	I97.200	54.992	220	896.708	638.886	7I,2
	I9I0	63.67I	398.553	I8I.487	23.I04	206.775	57.26I	24I	96I.994	629.262	65,4
	I9II	64.43I	4I0.82I	2I5.037	24.065	2II.459	57.I92	267	I.002.4I6	596.009	59,5
	I9I2	65.663	430.234	239.I06	26.596	232.263	62.224	282	I.074.943	622.472	57,9
	I9I3	67.04I	445.284	268.5I7	29.055	256.694	67.983	302	I.I64.5I9	688.797	59,2

Paper No. 77

THE STATUS OF RAILWAYS AND TRAMWAYS IN THE NETHERLAND EAST-INDIES.

By

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The extension of the rail- and tramway system in the Netherland East-Indies is closely in accordance with the general condition of the different islands forming that colony.

At the close of 1913, Java and Madura, forming an administrative unity with an area of 2388 geographical square miles and with a population amounting to 30 millions, had 2434 kilometers of railroads and 2109 kilometers of tram-lines.

Sumatra had, at the close of 1913, four separate systems of railroads and tram-lines, the total lengths of which are, respectively, 337 and 635 kilometers. The construction on the railways in Southern Sumatra did not begin until two years ago. The rest of the Archipelago (belonging to the Netherlands) has no rail- or tramways.

JAVA AND MADURA.

The development of the rail- and tramway net has followed various paths, the principle of railroad construction by private enterprise being first adhered to. The first line, from Semarang to the Vorstenlanden, with a branch line from Kedoeng Djati to Willem I, with a length of 206 kilometers, was entirely finished in 1873; the first part was ready to be opened in 1867. For this line, the State guaranteed a dividend on the capital outlay for construction, rolling stock, etc. On the other hand, after 99 years, when the lease expires, the railway track and everything belonging to it will become the property of the State, which will only have to pay a compensation for rolling

stock and some other minor items. This system of guaranteeing the interest was not applied in any other case; no financial help was given for further concessions.

The first railway was soon followed by a short line of 56 kilometers from Batavia to Buitenzorg, constructed and worked by the same company as the first line mentioned above. Further extension of the railway system was not due to private enterprise. When the extension of the system became more and more necessary, the State decided, in 1875, to itself start the construction and operation of railways. Only the line from Batavia to Krawang and from there to Kedoenggedeh was in later years constructed by a private company, which line, like that from Batavia to Buitenzorg—also lying in West Java and forming the first part of important State lines of great length—has passed into the hands of the State. As a result of the colonial financial policy, railway construction could not always proceed at a uniform rate, the railways being built from revenue, and no money raised to meet the costs. Only of late has the legislative power in the home country made money available on a larger scale. In all, 202 million guilders* have been spent for State railway construction in Java and Madura up to the end of 1913.

The reason why private enterprise has not cooperated more largely in the extension of the railway net is due to the small returns that may be expected during the first years of exploitation.

Without the help of the State, either by a guarantee of dividend or otherwise, the public could not, in many respects, consider railways a desirable investment. The State, instead of supporting private enterprise by subsidies or guarantees, has preferred to construct and work the railways itself. Yet private enterprise has energetically contributed to improve the means of transportation, namely, by constructing tram-lines, which, by their length as well as by their location are light railways rather than what is usually meant by tramways.

It is true that the tramways follow more or less the existing roads, but in other respects, the character of tramways has not always been preserved. On several lines the traffic has

* Guilder = $0.40.

increased so much in the course of years that simple tramway methods did not suffice, so that on some lines the reconstruction is already in progress, which will transform the tram into a railway.

To judge of the extent of private enterprise in this respect, it may suffice to state that at the close of 1913 there were 2036 kilometers of tram-lines in Java privately operated; the capital invested in these lines amounted to 95 million guilders.

Principles Governing and Costs of Construction.

As stated above, only a small amount of traffic can be expected, especially during the first years after the opening of a line. The fact that the island of Java is drawn out in length and has a great number of harbours excludes a dense traffic over long distance. Therefore, the cost of construction has to be as low as possible, while the capacity of the lines need not be very great.

When the first railway was being constructed with a gauge of 1.435 meters, the question was considered whether a narrower gauge would not suffice for Java, and even for the whole of the Netherland East-Indies. In accordance with a report drawn up by two experts, the normal gauge has been fixed at 1.067 meters, which gauge has been used on the Batavia-Buitenzorg line. Since that time, this latter gauge has—hardly without exception—been adopted for all the railway tram-lines; although since 1908, a width of 0.60 meter has been chosen for some tram-lines of minor importance.

At the end of 1913, 206 kilometers of railroads in Java and Madura had a gauge of 1.435 meters; 32 kilometers of tram-lines (in the adjoining towns of Batavia and Meester Cornelis), a width of 1.188 meters; 4222 kilometers of railroads and tram-lines, a width of 1.067 meters; and 83 kilometers of tram-lines had a width of 0.60 meter. So we see that the gauge of 1.067 meters, which has been adopted as the normal one, predominates in all respects.

The existing differences have, on the whole, caused little inconvenience, with the exception of the Djokjakarta-Soerakarta section of the Semarang-Vorstenlanden line.

Originally, this section was merely part of a line to the harbour-town of Semarang; later, its connections with the nar-

rower tracks have made it part of the main line which traverses the island in its greatest length. A provisional solution of the difficulty has been found by laying a third rail.

On examination we find that the gauge chosen has been justified by experience. The capacity of the 1.067-meter track has proved sufficient in all respects; so far the advisability of doubling the track has been considered for only one line, starting from the harbour town of Soerabaya. The operating expenses are not excessively high, yet average comfort can be obtained. The traveling speed attained is 65 kilometers per hour on the plains and 45 kilometers per hour in the mountains.

The speed on the plains will be considerably increased shortly; recent trial runs having shown that with specially constructed rolling stock the maximum speed can easily be made 120 kilometers per hour. Already, engines are in service which can draw 300 tons, exclusive of the tender, at a rate of 80 kilometers per hour on the level. At the same time, it has been possible to keep the cost of construction low; the State railway system in the mountainous, western part of Java had an original cost of construction of no more than 78,000 guilders (£6500) per kilometer, and for the flat, eastern part of Java, about 62,000 guilders (£5170). Of course, relatively large sums have had to be added for extensions and improvements. As the traffic increased, more or less had to be spent under this head, so that at the end of 1913, the capital outlay of the western lines stood at 96,000 guilders per kilometer; of the eastern lines, at 83,000 guilders. At the same date, the cost of the lines with a gauge of 1.435 meters stood at 151,000 guilders per kilometer.

Also for the tramways, the cost of construction has been very low. With the exception of the lines of the Batavia Electric Tramway Company, which, for various reasons, have cost 138,000 guilders per kilometer, the highest cost of construction, namely, that of the line Djokjakarta-Magelang-Willem I, amounts to 84,000 guilders per kilometer. This tramway, of which only about 20% was laid on the public roads, shows these high costs because a rackline had to be used over great distances. On an average, the tramways had cost nearly 46,000 guilders per kilometer up to the end of 1913.

It may be mentioned that for the railways with a gauge of 1.067 meters a rail section of 25.6 kilograms per meter has been used for a considerable time. This rail section, which, with few exceptions, has also been generally used on the different tram-lines, has been replaced on the principal lines of the State railways by one of 33.4 kilograms per meter. The maximum weight permitted on the axles of the engines is about 10 tons. The heaviest engine used in flat country has a total weight, in working order (exclusive of the tender), of 53.6 tons; it has three coupled axles, with 10 tons on each axle.

On the mountain lines, Mallet-Rimmrott engines have long been used, the heaviest of which, having 2 three-coupled axles and one driving axle, have a total weight in working order of 63.6 tons. Of late, a heavier type of engine has been used; it has 6-coupled (Gölsdorf) axles and a total weight, in working order, of 76.7 tons, of which 61.6 tons is adhesion weight.

On the 1.435-meter-gauge lines, the rail section has a weight of 41 kilograms per meter; the maximum load on the engine axles is 14 tons. The heaviest engine has a weight, in working order, of 65 tons, exclusive of tender, of which 53.2 tons is adhesion weight. It should be added that, for the railways with a gauge of 1.067 meters, 200 meters is generally considered the smallest radius for curves; only occasionally curves with a radius of 150 meters occur. In the high mountains, the track often presents very steep gradients; on the Padalarang-Buitenzorg line, two parts are found where, over a considerable distance, a gradient of 40 per 1000 is maintained.

Finally, we mention that, of the above rail- and tramway system, only 18 kilometers are worked by electricity. On several tram-lines and on some parts of the railway system, the change to electric traction is being studied and considered.

Nature and Amount of Traffic.

On the various railways and tram-lines, the goods traffic has developed very differently, according to the nature of the provinces traversed and according to their location. Traffic is, of course, greatest in the neighborhood of the different harbour towns, from which the goods are shipped for the world's commerce and where import articles arrive that have to be carried inland to the consumers. The greatest traffic is found on the

State's railway line leading to Soerabaya; then follow the lines connecting Semarang with the inland places.

The number of passengers is also greatest in the neighborhood of the large harbour towns; the exceptionally great number of travelers on the Bandoeng plateau is remarkable.

The following data illustrate the amount of traffic; the great increase in the last five years deserving special notice.

In 1903, on the different railroads, 2,253,000 tons of goods were transported; this rose to 3,371,000 tons in 1908; and to 5,193,000 tons in 1913. This is an increase of 54% in the last five years.

For the tram-lines, the corresponding figures were 1,316,-000 tons in 1903; 2,318,000 tons in 1908; and 3,423,000 tons in 1913.

So in 1913, as a total, 8,616,000 tons of goods were transported in Java and Madura.

The city tram-lines excluded, the number of travelers rose from 33,016,000 in 1903, to 50,328,000 in 1908, and 83,110,000 in 1913; so, in the last five years the number of travelers increased 65%.

This growth is partly due to the extension of the railroad and tramway system during those years, and partly to the greater development of the regions through which the trains pass. The amount of goods per kilometer of line was 920 tons in 1903; 1930 tons in 1913. The number of passengers per kilometer rose from 8500 to 18,600 in those years.

The best comparison can be obtained when we take the average amount of traffic, which is the number of ton-kilometers, and passenger-kilometers, respectively, divided by the number of day-kilometers. Then we see that the average goods traffic rose from 200 in 1903, to 360 in 1913; that of passengers, from 480 to 1020.

Traffic Returns—Financial Results.

As we have already mentioned, and as the above data show, railroad and tramway traffic in Java is not dense; hence, the traffic returns cannot be very great; it is only due to comparatively high tariffs that, on the whole, the financial results have developed favorably.

In 1903, the gross receipts of the State railways in Java

did not exceed 18.68 guilders per day-kilometer; for the private railway companies this was 42.72 guilders. In 1913, these receipts were considerably more favourable, namely, 37.49 guilders for the State railways and 67.47 guilders for the other lines.

For the different tram-lines, the receipts differ very much; the greatest returns per day-kilometer are made by the two city tram-lines of Batavia and Meester Cornelis, with 106.24 guilders and 43.49 guilders, respectively.

Of the other tram-lines, those with a gauge of 0.60 meter give the lowest returns. This was expected, as that gauge had been adopted where there was very little traffic; the returns are less than 8 guilders per day-kilometer.

Of the other tramways, the Babat-Djombang line has the smallest returns, namely, 8.81 guilders per day-kilometer in 1913; the highest returns of that year were made by the Djokjakarta-Willem I line, with 30.87 guilders, which is only 17% below the above-mentioned average of the State railways, or 37.49 guilders per day-kilometer.

The average returns of all the tramways per day-kilometer was 20.40 guilders in 1913.

These returns are mostly due to the traffic of goods; this predominates especially on the railways. In 1913, the total receipts of the railways were 36,067,000 guilders; 20,842,000 guilders, or 58%, being derived from goods traffic and 13,653,000 guilders, or 38% from travelers; personal luggage being counted as goods.

For the different tram-lines, in 1913,—again the two city lines excluded—the returns of passenger traffic were 5,573,000 guilders; those of goods, 7,620,000 guilders.

When we see how those returns are obtained, we find only few differences of any importance in the tariffs, as far as the final results are concerned. The returns per ton-kilometer for goods on the State railways were 4.5 cents* in 1913; for the private companies, they were 5.2 cents. The tram-lines show slight differences.

The lowest returns are found on the Goendih-Soerabaja line and for the Madura Steam-tram, with 3.7 and 3.1 cents per ton-kilometer, respectively; the highest, on the Solo-Bojolali and

* Netherland Cent = 1/100 guilder = 0.4 American cent.

Djokjakarta-Magelang-Willem I lines, with 13.68 and 10.6 cents per ton-kilometer.

The average returns per ton-kilometer for all the tram-lines were 4.7 cents in 1913; for the railways and the tram-lines together, 4.6 cents.

These figures prove that the goods tariffs must be rather high; though we should not forget that, owing to the long-drawn-out shape of the island, goods are generally transported over short distances only. The average distance is only 69 kilometers, so the price paid per ton remains low.

The above-mentioned large increase in traffic during the last few years probably shows that for the present situation the cost of goods traffic is not at variance with existing conditions.

Passenger traffic, by tram as well as by train, shows little difference in the returns per unit; the average returns per passenger-kilometer on the railways being 1.2 cents; on the trams, 1.1 cent—the two city trams again excluded.

The highest returns per passenger-kilometer are found on the Solo-Bojolali line, with 1.41 cent; then follow the Djokjakarta-Willem I line and the Rambipoedji-Poeger line, with 1.3 cent; while the lowest are found on the line of the Pasoeroean Steam-tram Company, with 0.7 cent.

The traffic can also show a great increase, though, in connection with the existing rate of wages, the passenger tariffs may be considered high. Here, also, traveling takes place over comparatively short distances; on an average, a passenger does not travel more than about 20 kilometers. It may be considered necessary to lower the prices, especially for long distances, now that the tendency to travel longer stretches becomes more and more apparent.

When finally we examine the financial returns on the capital invested in railroads and tram-lines in Java and Madura, they may be considered very favorable. Here, also, the later years, and the late increase in traffic, have contributed to attain those favourable results.

At the end of 1903, the capital invested by the State amounted to 137,639,000 guilders; the cost of construction of private railroads and tram-lines amounted to a total of 91,926,-

000 guilders. The net balance of the working expenses for that year (1903) was, respectively, 4,822,000 guilders and 4,969,000 guilders; that is, 3.5% and 5.4%. On the total sum, 4.3% was made.

For 1913, the corresponding figures are 185,515,000 guilders and 119,866,000 guilders for the amounts invested, respectively, in State and private railroads and tramways. The net balance was 13,328,000 guilders and 10,151,000 guilders; that is, 7.2% and 8.5%. So all the capital invested in railroads and tram-lines in Java and Madura gave an interest of 7.7% in 1913.

These figures prove that the railroads and tram-lines are, on the whole, profitable enterprises; the largest private company could pay a dividend of 17% in 1913. Only three companies, together possessing 131 kilometers of tram-lines, could pay nothing on their shares in that year.

RAILROADS AND TRAMWAYS IN THE OTHER ISLANDS OF THE NETHERLAND EAST-INDIES.

We mentioned at the beginning of this article that only Java possesses anything like a considerable number of rail- and tramways. In the other islands, only Sumatra has four railway systems, independent of each other; they are partly completed and partly in construction.

The oldest railway system in the famous tobacco district of Deli is due to private enterprise. At the end of 1913, it had 92 kilometers of railroads and 170 kilometers of tramways with a gauge of 1.067 meters.

Constructed to serve a flourishing branch of cultivation, the financial results are exceptionally favourable. In 1913, 15% dividend could be paid to shareholders; the capital invested was 19,424,000 guilders; the net balance over the working expenses was 1,923,000 guilders.

On these lines, also, goods traffic predominates. Of the total returns of 3,442,000 guilders, only 1,285,000 guilders, or 38%, was paid by the travelers.

These financial results are (still more than is the case in Java) due not so much to the amount of traffic as to the exceptionally high tariffs on the different lines.

Altogether, 3,163,000 passengers and 613,000 tons of goods were transported; amounting to 57,431,000 passenger-kilometers and 19,630,000 ton-kilometers.

The returns for the railways were 10.3 cents per ton-kilometer and 2.2 cents per passenger-kilometer; for the tramways, 8.8, and 2.1 cents, respectively.

The tramways in the district north of Deli, in Atjeh, present quite a different character. There, military considerations led to the construction, mainly along the coast, of a tram-line with a gauge of 0.75 meter, which, originally, was chiefly intended for the transportation of troops. When gradually more normal conditions arose in this district, the tram-lines also furthered the economical development.

For some years, it has been attempted to connect the Atjeh line with the Deli railway; which connection, when completed, will be of great advantage to both the districts.

The cost of constructing the Atjeh tramway, which remains under military control, amounted to 18,544,000 guilders at the end of 1913, or about 40,000 guilders per kilometer.

Though the gauge is very narrow, it has not been possible to construct the lines at a lower cost; the extraordinary circumstances under which the tram-line was laid down certainly account for this.

Altogether, 2,637,000 passengers and 114,000 tons of goods were transported in 1913, with an average return of 1.1 cent per passenger-kilometer and 3.6 cents per ton-kilometer. The net balance over the working expenses was 114,000 guilders, in 1913; that is, not quite 0.6% of the amount of the cost of construction.

In the western part of the island of Sumatra, a system of district railways has been constructed by the State especially for the benefit of a colliery in the mountains, which mine is also worked by the State.

As the central mountain range of Sumatra presents at that place a steep slope toward the sea, the construction of the railroad met with great difficulties; a rack line had to be constructed over long distances. The cost of construction was exceptionally high; it amounted to 97,000 guilders per kilometer

at the end of 1913. At that time, the total length of the lines was 245 kilometers.

In that year, 405,000 tons of goods and 2,701,000 passengers were transported along these lines; the returns per passenger-kilometer were 1.4 cents; per ton-kilometer, they were 2.3 cents. The net balance was 859,000 guilders on a cost of construction of 23,734,000 guilders; that is, 3.6%. This figure, however, does not exactly represent the financial situation, as the tariffs for the transport of coal from the State-owned mine along the State-owned railway do not even make good the cost.

Finally, we mention the railways in South Sumatra. Only about ten kilometers are opened, 450 kilometers being under construction; yet the principles underlying those works are worth considering.

Up to a short time ago, only such lines were considered fit for construction by the State as might yield adequate returns within a shorter or longer time, and where the indirect advantages also justified the necessary outlay in money. Indeed, the State railways and tramways in Java have, from the beginning, yielded not inconsiderable returns. The experience derived from other countries taught, however, that to further the right development of the colony, the construction of an adequate system of railroads should precede the cultivation of the land. A fertile soil, even when rich in minerals in various places, but without railroad communications, is not sufficient to induce the investment of capital.

The example given by other colonies was followed in the Indies, in the first place, by the construction of railroads in South Sumatra.

The necessary plans were made and a credit of 35 million guilders asked of the legislative power in the Motherland for the construction of 460 kilometers of railroads, to be completed within six years. The 35 million were granted without difficulty; the unanimity with which the plans were approved justifies the expectation that in future large credits will be voted to extend the lines of the State railways, so that soon not only Java, but also the other islands of the Netherland East-Indies, may possess an extensive network of railroads and tram-lines.

RAILROAD LEGISLATION—CONCESSION CONDITIONS.

Railroad legislation in the Netherland East-Indies differs little from that in most countries of Europe; the principles may be said to be the same. Without a too strong regulation, the duty of the railways to serve the public is sufficiently emphasized to guarantee its interests. It should not be forgotten that important conflicts have not occurred, so far. There is a tendency to introduce further regulations on these points where such may prove necessary. In 1866, the first "railway act" was passed, followed in 1886 by the first "light-railway act". The tendency of the latter has been, by simplifying the regulations, to lighten the burden of such railways as work with inconsiderable traffic and low speed.

It is remarkable that private companies do not run railways under the "light-railway act"; it is only applied to some State-owned lines.

The regulation of tramway traffic also presents a peculiar growth. When the first concession was granted, it was thought that a tramway could be used only for unimportant traffic and for very short distances. So the maximum speed was fixed at 15 kilometers per hour; the greatest length of a train of tramcars at 40 meters. Gradually, however, the character of the tramways changed. Constructed over great distances, they more and more became part of the main traffic system, rather than being of local importance only. It soon became necessary to permit a heavier traffic along these tram-lines than the fixed maxima allowed. So we see those maxima gradually raised, which is followed by additional regulations for the prevention of accidents.

In the end, we find a very considerable traffic for which a tramway regulation is made to suffice; which means that the public does not enjoy the guarantees for safety, etc., which they might expect. Therefore, a revision of the railroad legislation has been made, which has preserved the principle that speed forms the distinction between railways and tramways; the limit for tramways being fixed at 30 kilometers per hour. At the same time, the railways, as well as the tramways, are divided into primary and secondary lines; the limits of speed being 15

and 45 kilometers per hour, respectively, for the distinction of the tramways and of the railways. It is to be expected that, in this way, regulation will be more or less extensive in proportion to the amount of traffic and the resulting speed of traveling.

Among the conditions stipulated in the different concessions for the private railway companies, we mention the following:

For one line only, the above-mentioned one from Semarang to the Vorstenlanden, has the State given financial support; this was done in the form of a guarantee for interest. None of the other concessions received such support.

The principal regulations speak of stipulations made necessary by the geographical location of the lines, etc. In all regulations, the right to nationalize the railways is stipulated; the only exception being one tramway line for which a concession has been given for an unlimited time, whereas for all other lines it expires after a certain period.

Several principles have been followed in the course of years for the fixing of the amount which was to compensate for the nationalizing of a railway. At first, the idea was to repay the commercial value, i. e., the amount was fixed at twenty-five times the average net balance of the last years. Later, concessions have been granted in which the nationalizing amount was fixed by deducting from the final amount of construction expenses a certain sum for depreciation of rolling stock.

Of late, a method has been followed which lies between the other two, and in which the compensation for nationalizing approaches the final amount of construction expenses in proportion to the number of years which have still to elapse till the date at which the concession expires.

As nationalizing a railway is, after all, the only way to put a final stop to undesirable conditions, the principle of fixing the amount of compensation is too important not to speak of it at some length.

In conclusion, we give the following tables containing information about the development of railroads and tram-lines in the Netherland East-Indies in the last decade.

Length of Railways and Tram-Lines Working at the End of the Year (in km).

	1903	1908	1913
Railways	2,349	2,496	2,771*
Tramways	1,990	2,651	2,744

* 206 km. 1.435 m. gauge
32 " 1.188 " "
4,729 " 1.067 " "
465 " 0.75 " "
83 " 0.60 " "
18 " are operated electrically.

Total of Construction Cost (in guilders).

	1903	1908	1913
Railways	192,199,000	218,751,000	264,033,000
Tramways	70,946,000	100,652,000	125,675,000
Per km. railway	81,800	87,600	95,300
" " tramway	35,650	38,000	45,800

Working Expenses (in guilders).

	1903	1908	1913
Railways	18,914,000	26,152,000	40,779,000
Tramways	6,141,000	10,614,000	16,396,000
Railways, per day-km	22.10	28.86	40.31
Tramways, per day-km	8.60	11.24	16.76

Net Balance of Working Expenses.

	1903	1908	1913
Railways	8,151,000	12,223,000	19,628,000
Tramways	2,836,000	5,185,000	8,213,000
Railways, per day-km	9.52	13.49	19.40
Tramways, per day-km	4.00	5.49	8.39

Net Balance in Percent on Construction Cost.

	1903	1908	1913
Railways	4.2	5.6	7.4
Tramways	4.0	5.1	6.5
State-owned lines	3.3	4.3	6.2*
Private companies	5.5	7.5	8.6*

* For these figures, the results of 1912 had to be taken.

Amount of Traffic.

	1903	1908	1913
Goods ton-km	326,911,000	425,770,000	675,509,000
Travelers km	767,553,000	1,158,024,000	1,939,533,000
Number of tons of goods	4,087,000	6,605,000	9,826,000
Number of travelers	42,538,000	63,392,000	106,131,000

Distance Covered.

	1903	1908	1913
Number of engine-km....	21,708,000	27,240,000	35,705,000
" " train-km	18,752,000	22,642,000	28,294,000
" " axle-km	354,955,000	533,350,000	786,453,000

Rolling Stock.

	1903	1908	1913
Number of locomotives	832	970	1,134
" " carriages and luggage-vans	1,604	2,157	2,846
" " trucks	9,536	12,196	19,015

Paper No. 78

ECONOMIC CONSIDERATIONS CONTROLLING AND GOVERNING THE BUILDING OF NEW LINES.

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The subject of this paper is one to which a very general, or a much detailed interpretation may be given. Broadly speaking, and adapting somewhat from Webster, it signifies the correct and frugal management of resources, or capabilities of producing wealth, the proper manner to handle ways and means, so that the desired end may be best and most economically achieved.

Certain principles can be set down, which are not original, but which have been recognized as axiomatic:

That with due regard for true economy, only minimum capital should be expended that will produce the desired results.

No increase in such minimum is justifiable, unless it can be clearly shown that it will increase net profits.

No outside investment is justifiable, unless it is reasonably apparent that it will increase net profits, and not then, if it will take from the funds provided, sums which are needed for the proper construction of the road itself.

The conditions under which many of the present railway systems of the United States have grown up, were very different from those which prevailed in any other civilized country in the world, and those conditions, excepting to a very minor extent, exist no longer with us. In the older countries, the centers of trade and population became well defined, beyond any probability of change, before steam, as a tractive power, became a factor in the situation. With these centers definitely fixed, and with the character and amount of the traffic between

them a known quantity, subject only to small fluctuations, the matter of designing and building the proper tool to handle it became a comparatively simple task.

The problem presented to our predecessors was from its nature much more complicated. An immense territory hardly known, as far as its detailed physical features or material resources were concerned, embracing every variety of climate and topography known to the temperate zones, became with wonderful rapidity the homes of millions of people, drawn not only from our own sparsely settled seaboard states, but from almost every country in the world: A mixed population of different races, habits and capacities, all seeking a permanent abiding place, and room for the energies of themselves and their descendants for all time to come. There was little time for study and analysis to enable an accurate forecast of the future to be made, as the demand became and continued absolutely insistent for swift exchange of people and products, not only between interior points, but between such points and the seaboard. And with a faith—we can call it nothing less—which was almost sublime, our fathers planned and built new, and extensions of existing lines far into and across lands where no paying traffic was assured, and which were inhabited almost exclusively by savages and wild animals; and unconsciously, these men erected for themselves as noble a monument as ever commemorated human achievement.

It is undeniably true that were the theoretical problem presented to us today, of planning a system to handle the present traffic of this country, with the conditions as they now exist, the result, while resembling in its general features the railway map of the present time, would differ materially from it in many details; but no engineer or operator of our period, with all his advantages of technical training, of precedent and example, has any justification for adversely criticising his predecessors, when in their day, not only the financial means, but the very tools and men to work them, had to be evolved largely through their own unassisted efforts.

A railway is simply a machine for the conducting of transportation, and the laws which should govern its planning and building are the same as those governing the planning and

building of any machine, and such laws, properly administered, will create one fitted to do its work the most efficiently at the least cost in fixed charges and operation. And as the engineer is largely the man to whom is entrusted this duty of "making a dollar earn the most interest," it follows that there are certain definite essentials in each individual case, which he must carefully consider if his labors are to be crowned with success. The amount and nature of the prospective traffic, its character as regards rates, length of haul, cost of handling, as affected by speed, liability to claims for damages—its density, whether constant or fluctuating, balanced or badly unbalanced, whether wholly local or partly local and partly through, are all factors which must be carefully studied out, to enable an intelligent forecast of probable results to be made.

Railway lines are planned and built to handle traffic, and the general principles upon which they should be planned are the same whether they are to develop new territory, that is, territory not already served by existing lines, or whether they are to share in a traffic already built up, in other words, to become competitors to divide with other lines a commerce that may or may not be certain of future growth.

It is apparent to students of transportation in the United States, that the creating of large systems, by actual construction, is past, and that while it is obvious that many miles of railway lines yet remain to be constructed, such mileage will be made up largely of branch roads, built to round out, to provide feeders for, and to protect existing systems; that the necessity for new main lines, excepting in a few isolated and unique sections, is not at present manifest.

The study of the conditions leading up to the contemplation of all such new lines, involves the same general problems, such as whether or not the line should be built at all, and if so, then where and of what character and cost. Railways are built to make money for their owners, and not as a rule from motives of philanthropy. Such then, being the case, the consideration of balancing the safe probable income (gross earnings) against the probable outgo (fixed charges, taxes and operation) becomes the all important one, and the study of this consideration presents a separate, distinct problem in each individual case.

When an established, successful system contemplates the building of a branch line requiring the providing of additional capital, it usually guarantees the bonds of such line, which renders the necessary financing an easy matter. The question of the earning power of such new line differs materially from that of a separate, independent proposed line; as, while the latter must depend upon its own strength to become a paying proposition, and while the former might in itself prove a losing investment, the long haul traffic it would give to the system, as a whole, would prove the wisdom of its creation. There is hardly a railway system in the United States, especially in the West, that does not afford examples of the truth of this statement. Many of the branch lines of such systems were added to them by purchase, and while the yearly financial balance of such branches, as the accounts are kept, may show on the wrong side, still, every official knows that the strength and support they give to the main lines, far outweigh any apparent loss, which they themselves may indicate.

It may be set down as a rule: that in order to secure capital for the building of a new independent line, the probable results to be expected must show at least ability to earn operating expenses, taxes, fixed charges, and a sum over and above at least twice these amounts, to be applicable to sinking fund and dividends. Such requirement may seem to be unduly onerous to the eager promoter, but it is an economic financial consideration, and if it cannot be closely approximated, then the enterprise had better be dropped, and the energies devoted to it turned in other directions. And this phase of the problem brings sharply to the front the conservative care with which the data should be collected, analyzed, classified and summarized, that are to be used to interest capitalists to finance the proposition to a certain assumed amount, for the time being. Under such a program the approximate cost per mile, or total cost of the new line, as well as its operating expenses, must also be assumed, in which assumption the engineer and operating man must co-ordinate; but when the probable financial results can be reasonably predicated, then the real work of the engineer will begin.

The consideration of the probable safe financial results,

which must control the building of a new line, is one to which is rarely given the amount of study which the conditions demand. The path of railway planning and building in the past, in the United States, is strewn with the wrecks of the hopes and fortunes of promoters and capitalists who have been lured to disaster by overheated imaginations and unwarranted assumptions in the shape of apparent traffic certainties, which, in most cases, a cold, careful, logical analysis made by competent, conscientious, experienced traffic men would have been clearly shown to be impossibilities. None but such men should be entrusted with the securing and preparing of such data, and no factor, great or small, which might affect this result, should be overlooked. What may be termed a house to house canvass covering all of the entire territory, which the new line can reasonably be expected to serve, should be made. Markets, connections with other lines, divisions of rates, probable competition, are most important factors to be carefully studied. The character of the country which the new line will traverse, and its probabilities as to future growth, based not only on its apparent resources, but on the results which experience shows have been obtained in similar sections and under similar conditions, should be thoroughly investigated.

It is a well known truism that traffic, like water, will always follow along the lines of least resistance, and while temporarily it may seem to contradict this rule, in the end the old natural law of the survival of the fittest will prevail; and it is dangerous to assume, on account of financial or other restrictions, that if the new line cannot be made as good a transportation tool as its competitor, it will get any substantial part of the business. This is not a true assumption, for the handicap which will drive the major part of the traffic away from the new line, will drive much of the minor part away also.

Other considerations from those noted above have governed the building of some lines, such as roads promoted by communities or sections, in order to relieve monopoly so-called, either real or imagined. These attempts have generally proved disastrous for the promoters and financiers who were responsible for them, and resulted in no lasting benefits to the public at large. Planned and built by parties having no practical

experience in the essential economics underlying the railway business, they have generally fallen into the ownership of the stronger lines, with the result that upon the public, in the end, was thrown the burden of additional carrying and operating charges, without any relief in rates and little improvement in character of service.

Under our present regulation of railways by National and State laws, it is probable that such attempts at railway expansion will be infrequent in the future, as such regulations would seem to render them unnecessary, and it is a safe assumption that hereafter, new lines will only be built where economic conditions fully justify their construction. Neither will such lines be built in order to provide means for employing idle capital. The present outlook and the situation in which the railways have been placed during the past few years, offer little encouragement to expect that capital will seek an outlet for its energies along the lines of new railway promotion. Safety first, and the much more attractive openings for idle funds, will divert them to a great extent, into channels where more reliable returns can be expected, and where legitimate enterprises are not hampered and throttled down by the vagaries of political law makers.

There are other factors, which may be called politic rather than economic, but which, if wrongly handled will most surely affect the general result. The importance of creating and maintaining cordial relations with the communities whose friendship and support are so essential to success, should be clearly recognized, and such relations should be established and maintained.

In the matter of financing, the soliciting or accepting of local aid, as a rule, is of more than doubtful benefit, such aid, excepting possibly the fixing of reasonable prices for real estate, in the aggregate is ordinarily a negligible quantity. And too, the acceptance of such aid is usually construed by the public as imposing obligations on the railway company that are likely to cause embarrassment in the future.

The printing and distributing of vast amounts of stock among promoters, should not be encouraged. Such stock is of doubtful value until a good earning power of the road has been demonstrated, and its issuance, excepting in very limited quan-

tities, is certain to become a handicap in dealing with hard-headed financiers.

Such, in a general and preliminary way, appear to the writer to be leading economic considerations, to which the most careful thought and study should be given in working out any new proposition to build new, or to extend our present lines of railway transportation. Not only must present conditions—agricultural, commercial, financial and legal—be carefully weighed, but past experience must be consulted, if even a fairly accurate forecast of the future can be expected. As little as possible should be taken for granted, and a liberal discount should be made upon all factors, which, from their nature and uncertainty, cannot be proven beyond a reasonable doubt. "Hope springs eternal in the human breast," but hope is a very insecure foundation upon which to erect a railway structure which will stand the storms of hard experience and sharp competition. Once, however, all the necessary data have been collected, carefully sifted and summarized, and the decision has been reached that the building of the line is a necessity, that it can be fully justified, and that the proper financial support can be found, then there enter into the proposition certain problems, which, while they are largely physical, are yet of great importance; and the manner in which they are handled, in connection with the purely economic questions, may make or mar the enterprise.

These problems cover the actual planning and contructing of the physical road itself, in giving it a constitution and members suited to its needs, in short, to make it the kind of tool best adapted to the work it is to do, and it is these problems that it is peculiarly the province of the engineer to solve. The nature and amount of the expected traffic, as well as the country to be traversed, are the controlling factors, the proper appreciation of which must determine the physical characteristics of the proposed line. The engineer must approach the subject with an open mind, ready to receive, weigh, accept or reject every possibility which may be suggested, and to remember that no supposed natural gifts, or flights of the imagination will take the place of a cool, careful analysis of all the conditions as they are presented.

The growing recognition of the fundamental truth that the planning and building of a railway is an exact science, and not a rule of thumb matter, will be of inconceivable benefit, not only to the railways of the future, but it will also tend to elevate the professional status of the true railway engineer to a plane which, in many cases, his right to occupy has not been generally understood and admitted. The economics involved in the building of a new line, should only be entrusted to a man who is not only a good technical engineer, in the broadest sense of the word, but he should also have a practical knowledge of the intricacies of handling transportation, the best and most economical methods of maintaining railway properties, and also, in a general way at least, the effect which the working out of the details of his problem will have on attracting traffic to the line or repelling it. A coordination of the various kinds of knowledge embraced in the above, in the hands of a man possessed of judgment and discrimination, should fit him to become what the writer has termed a true engineer. He should be furnished, not only with the general factors which made up the decision that the line should be built, but he should also be conversant with the details. This is especially true where the road will naturally enjoy a good local business, instead of being a bridge built mainly to haul traffic from a producing to a consuming point, across long stretches of unproductive territory. With a line of the former character, there is hardly a mile of its entire length where its character and cost of construction may not be affected by its prospective local business.

The probable proportion as between passenger and freight earnings, as well as the character of each class and their relative importance, are factors to which careful attention must be given. Ordinarily, in terms of both earnings and expenses, the freight will largely predominate, but too much prominence should not be given to that feature, as the comfort of passengers must be provided for, and while a road with easy grades and comparatively heavy curves may economically handle heavy freight, it must be remembered that human beings will complain—and justly—while dead freight will not, if hurled at high speeds over such a road. The mixture of passenger and freight traffic is a handicap, which prevents the engineer from

working out a perfect machine, but he must adjust his plans to meet the conditions, and not sacrifice the interests of either class entirely to the other.

Unless, however, the road is to be built to compete for highly remunerative passenger traffic, the one fact alone, that usually from 65 to 80% of the earnings come from freight, should emphasize the importance of securing the lightest grade the country will reasonably admit of, even at the expense of the introduction of somewhat heavier curvature than high-speed passenger service will demand. Concrete instances could be given where failure to appreciate the importance of this consideration, has resulted in serious detriment to the future value of railway properties.

A careful study, commonly called reconnaissance, of all the territory to be covered by the new line—a study which will give the engineer a correct mental picture of it in all its physical features, geographical and topographical—is a very important, economical necessity. As a rule, no instrumental surveys (other than individual, by aneroids, etc.) should be attempted, until such a picture is fully complete in the mind. More mistakes in the essentials of location have been made, and more miles of poorly located line have resulted from the assumption of arbitrary rates of grades and curvature, and attempts to fit such standards to an unknown topography, than from any other cause. Find the theory to fit the facts and work it out, not the facts to fit the theory.

In other words, true economics demand that the engineer shall, when all data as to traffic and details of country are known to him, then evolve a line of such character that will come nearest to meeting all conditions, instead of trying to force a preconceived line of certain character on the country to handle its traffic. Once he has solved the general features of the problem, the rest are matters of detail, and with the application of the same recommended principles, he cannot go far wrong.

He must remember that in the operation of the road, its financial status is, in the last analysis, like that of the individual —dependent entirely upon its income and its outgo; and these terms mean, in the case of the former (as far as freight is con-

cerned), ton miles (income) and train miles (outgo), and his problem is to build a road that can handle the greatest number of ton miles, with the least number of train miles. That is all there is to the proposition. And it does not necessarily follow, that the lightest possible grade he can force through the country is necessarily the most economical one. An unnaturally light grade, may, and in many cases will, involve such length of line and such enormous cost of construction (necessitating not only abnormal fixed charges, but cost of maintenance, all of which will be reflected in heavy train mile expenses) that it will be found that a heavier grade, by reason of its shorter line, less expensive construction and better alignment, will prove, with proper adaption of power, to produce the more economical results.

Again, like the individual, it is not so much what the road can earn gross, as to what it can save—its net. The writer is not attempting to argue as opposed to light grades. Light or heavy grades are comparative terms, and it is the grade over which the business can be the most cheaply and efficiently conducted that should be adopted, regardless of its percentage. The introduction during the last few years, of a certain class of locomotive, whereby enormous tractive power is obtained, without materially increasing strains on track or bridges, has introduced a different factor into, and to a great extent, has simplified the problem of gradients, especially on heavy mountain lines. In other words, where formerly restrictions in tractive power were necessary, to make wheel loads conform to strength of track and bridges, it is now possible to practically double the tractive force, and consequently, the gross load per train, without additional distress to permanent way. And in this manner, the effect of lightening or levelling up of grade lines, can be made practicable with marked decrease in train miles, and with a negligible increase in operating expenses and fixed charges. Of course, such a policy cannot be pursued in the majority of cases, but it can be in many, and it is a valuable point in railway economics for consideration.

Another economy, to which the attention it merits is seldom given, is the consideration of so-called ''pusher grades''. Time and space here will not permit of a technical analysis of this

important subject. It is a fact that the prevalence of opinion among railway operating men is against the use of such grades, and for which opinion no special reason can be given. Again, the question comes squarely back to cardinal principles: fixed charges and train miles. In many cases, where long stretches of non-revenue producing mileage would be forced to maintain a continuous light grade line, with abnormal expense in construction and maintenance involved, a thorough study of the value of pusher grades would surprise some engineers, who have been prone to give them no consideration.

The matter of maximum rate of grade being decided, then its distribution becomes a problem of importance. Economical movement of trains demands that they shall be moved, not only with as large a tonnage as time will permit, but that they shall be moved solidly for the greatest distance practicable, both to avoid loss of time and cost of intermediate switching. Thus, if the proposed line is to be more than the economical length of one engine run, then the grades of each separate operating run must be worked out as an individual problem. And wherever any difference in rates of maximum grades may exist between different runs, it should be eliminated by adaptations of different classes of power, so that a continuous, unbroken movement of a uniform tonnage train can be made over the entire road.

When we reflect that the average daily movement of a freight car is less than one-fourth of the daily mileage that the railways are paying train and engine crews for, it becomes very apparent that the fewer inducements that are given for holding up and switching a train, the better will be the operating results. The comments which an old President made when he refused to approve a request for funds to build an additional yard, that "he would appropriate money to take up some of the existing yards to see if he couldn't get cars moving", contained a very large germ of wisdom.

The economic adjustment of grades, in cases where the traffic is unbalanced, presents a complicated problem. Many times, however, this question is simplified by the nature of the country, as in case of roads built to handle the products of mines, which are often situated in high altitudes. In such cases, the problem is usually solved by the topography of the country, and the necessary limitations in capital expenditure. No set

rules can be made to govern each case, but here is where the operating experience of the engineer, combined with his knowledge of construction and operation costs will, as a rule, produce the best results.

The whole question, economically considered, of the adjustment of grades and curvature, is one which no general rules can be absolutely made to cover. It goes without argument, that the lightest curves that can be consistently used, should be, whether the line is to handle fast passenger or slow freight service, or a mixture of both. There is no doubt but that the dangers of operation are materially increased by the introduction of a large amount of curvature, although it must be admitted that many of our most disastrous collisions have occurred on long tangents, in broad daylight. This, however, is where the human element asserts itself, and all we can do is to eliminate as many of the recognized sources of danger as is possible.

The effects of curve resistance, not only in the absorption of power, but in the increased cost of maintenance of track and rolling stock, are too well appreciated to need discussion here. The compensation for curvature, if properly applied, will largely eliminate the first handicap, although, as it is sometimes applied, without due consideration as to location of curve, speed and length of train, it is not of the full value that it should be. Practically each curve presents a problem which should be worked out on its own individual merits.

The consideration as to what extent so-called "permanent work" should enter into the construction of the line, as an economic measure, is one that must be governed largely by circumstances. There are times and occasions when the building of masonry structures, steel bridges, expensive stations, etc., cannot be considered. The comparatively cheap cost of timber in some localities, and the absence of definite knowledge as to required capacity of waterways, fully justify its use in many instances. It is true that a railway is usually richer during its period of construction, when it is working on borrowed money, than it is ever afterward, and this dangerous knowledge has lured many an engineer into heavy expenditures, which might have been postponed for years, with large resulting economy. In the construction of almost every new

line there are instances where the expenditure of large sums can be deferred for long periods, or until the road has, by constantly increasing earnings, fully justified such expenditures. Temporary gradients, sharp curves, etc., can often be used until the traffic and importance of the line have fully demonstrated the necessity for the permanent work. And under these conditions, the financing can usually be done, without the heavy addition to capital charge, which the work, if done originally, would have entailed.

The whole matter, however, is one requiring careful consideration, always remembering that the cost of supervision, engineering, law, right-of-way, rails, ties, ballast, buildings, signals, water service, and to a great extent, of bridges, is practically the same per average mile, whether the grading is heavy or light: in other words, light grades and easy curves involve what may be called the digging of a little more dirt. And by proportioning the cost of the above mentioned items to the total cost, the force of the suggestion may be seen.

But the economic consideration, which, it would seem from results, usually receives little attention, but which, without doubt, deserves very much, is the providing for proper terminals of a capacity not only sufficient for the present, but susceptible of enlargements for future requirements. It is a safe assertion that no other one cause, from a physical standpoint, contributes more to the high cost of operation, or is a greater handicap in giving good service, than the poor terminals of most of our railroads. It is frequently asserted, with much truth, that in many of our large cities, the cost of handling a car, or a ton of freight, from the time it arrives in the break-up yard to the consignee, and back again from the shipper to the same point, is as much as it costs to haul it 200 to 300 miles out on the open road. And right here the writer wants to emphasize that if it becomes necessary to economize (as the word is commonly used), do it out on the line but not at stations, and especially not at terminals proper, particularly in the amount—in area—of real estate secured. And these terminals should be located as near the center of commercial and manufacturing activity as possible, especially if traffic competition exists, or is liable to exist, as is generally the case.

Give the road between terminals a good constitution, in the

shape of a proper location, with proper grades, and it will stand a lot of adversity and come out all right, but handicap it with small, improperly located and badly planned terminals, and it is useless to expect either first-class service or satisfactory returns. The line of argument adopted by the projectors of many new lines, in building into or through an old town, where keen competition from roads long established must be expected, is that they cannot afford to pay the high prices for real estate demanded for land near where the business exists. So they will stay out in the edge of the town and get a part of it, forgetting that the reason which induces four-fifths of the business to seek the nearest station, will induce about all of the remaining one-fifth to do the same. And a road that will cheerfully spend from forty to eighty thousand dollars a mile on its main line construction, will refuse to spend the equivalent of the cost of three or four miles of such line to obtain proper stations and terminals near the center of towns fifteen to thirty miles apart, whose transportation business amounts to a million or more dollars each, per year. No question is more insistent today, and no matter what laws and regulations are forced upon the railways, or what rates they may be permitted to establish, they must—new and old—provide themselves with proper terminals, before they can expect good operating results and proper financial returns.

The field of railway promotion and building is still open, and the writer believes it will widen and become again attractive when the financial situation becomes normal, and when the general public understands and admits the community of interest which exists between it and the railways. The field is a legitimate one, but it must be cultivated on strict business principles, a few of which the writer has endeavored to point out.

DISCUSSION

Mr. F. Lavis,* M. Am. Soc. C. E. (by letter) said that at an International Congress held to celebrate the completion of a most important link in the transportation routes of the world, one which it is hoped will draw the countries of North and South America closer together, it seems not inappropriate to discuss the difference in the habits of mind and thought of American and European engineers; and this especially Mr. Lavis.

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Mr. Lavis. in view of the fact that they will both probably play important parts in the development of the South American continent by railways, a work which is destined to receive a great impetus in the not far distant future.

Mr. Stevens has pointed out the inherent difference in the transportation development of the two continents, Europe and America; in the former the railways have been built to link together existing developed centres of population with established commerce, in America they have been pushed forward into the wilderness ahead of civilization. The European has, therefore, developed almost wholly along purely technical engineering lines to produce a structure or a machine to meet conditions and to connect points fixed within fairly definite limits; the American has had to develop a sense of vision of the future. Both have achieved wonderful success in their respective fields; there have been of course some failures, possibly more in this country, owing to the conditions, but it must be admitted that these conditions have developed in North America an appreciation of the true science of the economics of location and construction which is often only dimly sensed elsewhere.

Mr. Stevens' paper is instructive, if for no other reason than that after a lifetime spent in the development of transportation routes and in the construction of railways he instinctively devotes nearly half his space to a discussion of questions of finance—will it pay? There is, and rightly so, as it is a mere detail in view of the higher considerations, little said about the detail of surveys or construction, but certain principles, which he alludes to, some of which are not as well recognized as they should be, deserve emphasis and are as follows:

(1) The necessity of studying the country and then determining the type of line which is the best compromise between topography and traffic rather than hunting for country to fit a previously conceived type.

(2) The flexibility and adaptability of modern power, and the possibilities of its use; and in this connection there might be added in some very few cases the possibilities of electric traction. This latter seldom comes into the field of view in the consideration of new lines, but the writer happens to know of one particular instance of some importance where it has, and of course its future possibilities are not known.

(3) The general principles governing the relations of grades and curvature to the type of traffic and the fact that earthwork costs are a comparatively small proportion of the total cost of the line, the latter a point too often ignored or forgotten.

(4) The need of providing adequate areas for terminals and station grounds.

One further point may be made, and that is the growing appreciation of the fact that the negative values of curvature, rise and fall, distance and the operating value of different rates of gradient vary with the kind and character of the traffic. Sharp curvature is more costly in the case of a fast passenger train which has to slow down for it than for a long, heavy freight train; additional distance may or may not be an added

Mr. Lavis.

element of cost, etc. The tendency is now toward dividing the traffic into classes, and for many items to attempt to fix a value per ton mile rather than per train mile.

It seems almost ridiculous at this late day to allude to the necessity of careful surveys once the general route has been decided on. In this the Europeans have been more generally consistent and careful than we have, and even today, although Mr. Stevens assumes as of course that such will follow, it is too often true that they do not; and even at this late date many of those who pay for construction fail to recognize the truth of Wellington's statement that it is "cheaper to move dirt with a transit than with a steam shovel."

Paper No. 79

THE LOCATING OF A NEW LINE.

By

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Following the decision to build a new line of railroad, the terminal points of which are defined, is the actual work of suitably locating the railroad.

Suitably locating the railroad is designing its grade system and its center line in such a manner as to produce the most satisfactory investment for the owners.

The most satisfactory investment for the owners, if of possible correct determination, might result in a materially different railroad, as first constructed, for instance, for owners not possessing a railroad of which the proposed new railroad is to become an extension or a branch, than for owners possessing a prosperous railroad of which the proposed new railroad is to become an extension or a branch, for the reason that a new railroad that is not an extension or branch of an existing railroad cannot endure so long a period of annual operating expenses and annual interest on the investment, together amounting to a sum in excess of its gross receipts, as can be endured by a new railroad which is an extension or branch of a prosperous railroad, to which it also contributes new traffic.

For instance, with compound interest at four percent annual rate, and net revenue when operation begins equal to 46% of annual interest on the investment, and net revenue at the end of five years equal to annual interest on the investment, and net revenue thereafter increasing at the rate of 20% per year, it will require more than eight years from the date of commencement of operation of the road for recovering the

losses of the first five years, and the increase in business may not be so favorable as assumed.

Evidently the question of whether to build a railroad in reference to the expected traffic of the very near future or of a more distant future is of the first importance to the investors, and should be decided on by them as affecting the character and cost of the railroad which they desire to have located or designed.

Some important portions of the investment can be regulated in amount by the character of the buildings, structures, track, ballast, etc. The necessary amounts of grading, tunneling, sundry forms of masonry, and structures, are controlled by the location, as well as the future operating expenses of the railroad so far as they are affected by the curvatures, grade systems, and length of railroad.

The most important matter is the determination of the grade systems, which if reasonably practicable should be of such ruling grade rates that they will not require change with any future increased traffic, that is, they should be the best practicable in reference to topographical conditions. Although this is not always possible with financial conditions under which the road is built, it is frequently possible and advantageous. In such cases, reduction in first cost can generally be made by the use at occasional points of sharp curvature to avoid tunnels and to avoid or lessen grading work of unusual magnitude and cost.

A railroad so built with proper grade system will have hauled over it from the commencement of its operation, as heavy loads, of the sundry classes of locomotives, as will ever be possible, with the relatively minor objections, to the temporarily used sharp curvature, of the cost of resulting wear, and of operating over the extra distance, and possibly, the necessity for reduced speed for short distances.

The future rebuilding of such a railroad, when warranted by traffic increase, will consist of occasional short reconstructions, instead of the abandonment of considerable lengths of railroad.

The grade system of a valley railroad or of one through an undulating country which has no great differences in eleva-

tion—if it is the most suitable grade system attainable—can, if necessary, be broken in the interest of cheapening the first cost of construction by the introduction of the well known expedient of velocity grades for use during the first years of operation, these velocity grades advisably having a maximum rate which is not in excess of the grade rate up which a fully loaded freight train can double, with half its load.

These grades sometimes result in extreme unpopularity of the road amongst its passengers, unless the road is maintained in improbable excellence.

In cases where a valley country grade meets the steeper grades required for surmounting a mountain range, the question of the advisable steeper grade becomes important as affecting cost of construction and cost of operation; and with suitable advance consideration of the matter, it sometimes occurs that the most desirable grade system will cost little or no more to build than a less desirable grade system which might be decided upon without due consideration.

It is sometimes the case that the use of the same class of locomotives on the valley road and on the mountain road is advisable, especially where the mountain grade is not necessarily of more than ordinary steepness, thereby reducing the number of classes of locomotives to be provided.

For instance, if the valley grade is four-tenths of one percent, and the freight trains are adjusted to be hauled on long distances of this grade at twelve and one-half miles per hour by one Consolidation engine with fifty-seven inch driving wheels, thirty inch stroke and twenty-two inch cylinder diameter, and two hundred pounds steam pressure in the boiler, two of these engines will haul the same train at the same speed up a continuous grade of about ninety-six one-hundredths percent, or at a slightly reduced speed up a continuous grade of one percent.

It would apparently be an unnecessary investment to expend considerable additional money to construct the road with a grade rate of less than one percent, especially in view of the fact that if in place of the two Consolidation engines on the one percent grade it ultimately became expedient to use, for instance, one Mallet Compound engine with fifty-seven inch

driving wheels and thirty-inch stroke, with cylinders of twenty-six inches and of forty inches diameter and with two hundred pounds steam pressure in the boiler, which would haul the same train up the one percent grade at a speed of about fifteen and three-tenths miles per hour, which increased speed might be considered expedient or could be reduced by some extra tonnage of delayed freight, etc., when desirable.

In a question of this sort as to desirable grade rates, the passenger trains need not be considered as controlling, but the effect of different grade rates may be illustrated by the following instance.

A passenger train of four hundred and fifty tons, exclusive of engine and tender, would surmount a continuous four-tenths percent grade at about thirty-five and eight-tenths miles per hour if hauled by one engine with seventy-seven inch diameter driving wheels, with twenty-eight inch stroke and twenty-two inch diameter of cylinders, with two hundred pounds steam pressure in the boiler, and the same one engine and train will surmount a continuous up grade of one percent at a speed of twenty-five and six-tenths miles per hour. If it should be desirable to put two engines of the same class on the same passenger train, they would surmount the continuous up grade at about thirty-five and seven-tenths miles per hour.

Instances can be multiplied as to varying grade rates, but the one already given sufficiently illustrates the advisability of consideration of the most desirable grade, and its adoption unless prevented by adequate reasons pertaining to the investment.

If a very steep grade will enable a mountain range to be surmounted with a radically smaller construction investment than is required for a more desirable grade, it is sometimes justifiable to so build, with the plan of thereafter, at a suitable time, abandoning the steep grade after the construction of a better grade system, when warranted by the traffic volume.

In this case it is desirable to know in advance of any construction work as to the position of the foot of each grade system, with a view of so locating the approach valley line as to require the future abandonment of as small a mileage of railroad as practicable.

This last-named expedient, of using a relatively temporary grade system for surmounting a mountain range, will sometimes result in so great a difference in cost of construction as to result in the difference between the financial success and the financial ruin of the original investors.

It is most important to have in view the fact that operating expenses can be adjusted, in a large degree, to variations in volume of traffic, and to a less volume than the anticipated traffic, whereas the interest on the investment cannot be so adjusted.

The introduction of curvature to reduce cost of construction of a valley or rolling country line is generally by the use of curves which are not especially objectionable as to sharpness and resulting reduced speed requirements and increased wear of track and rolling stock. The effect of such curvatures on running time of trains is sometimes over-estimated and unwarranted cost of construction incurred on this account, as well as in after years unwarranted cost of reconstruction.

This is well illustrated by the time of the Overland Limited, running east between Oakland Pier, California, and Ogden, Utah, which has certain speed restrictions running down very steep grades on which there is considerable sharp curvature, the running time of which train on account of other curvature is increased but eighteen minutes in a total distance of seven hundred and seventy-seven and four-tenths miles.

Illustrating by another instance: the time of the Fast Mail running west from Ogden to Oakland Pier has certain speed restrictions running down very steep grades on which there is considerable sharp curvature, the running time of which train on account of other curvature is increased but six and four-tenths minutes in a total distance of seven hundred and seventy-nine and one-tenth miles.

Evidently curvature effects, other than in increased running time of trains, exist in approximately defined but not thoroughly established values.

The introduction of curvature to reduce cost of construction of a railroad built on a steep mountain side or on the steep sides of a river gorge is generally justifiable to a degree that

might be considered extreme, particularly where the grade is so steep as to itself limit the speed of trains up grade, and where nearly as slow a speed is prudent on down grades, on account of the possibility of slides, minor washouts, rocks from mountain sides, etc., the objections to curvature in such situations not including the effect on running time of trains.

Careful engineering methods in such cases would include a consideration of the relative operating values versus the relative costs of construction of any portions of the line, where possible alternative lines were obvious. The worst error in such cases is where alternative lines are compared, neither of which is the proper line to adopt. To avoid this, and have a proper basis of comparison, the cheapest line which is reasonably practicable, within the adopted maximum grade and maximum curvature limitation, should be designed and used as a basis of comparison. When this is carefully done it will generally be found that with the transverse slopes of the mountain sides very steep, the cheapest line will prove to be the proper line to build, with conservative consideration of the probable traffic to be assumed as a basis for the computations.

The modern curve is located with easements at each end, variously termed spirals, easements and tapers, the latter being the term which will be used in this paper.

It is advisable that these tapers should be readily run out on the ground by measurements and transit deflections, similar to the methods used for the principal curve, and with the minimum amount of necessary field computations, for the reason that such field computations are unusually subject to error and particularly because they cost money unnecessarily.

The tapers furnish a means of superelevating gradually, easing the shock of the rolling stock in passing from tangents to curves; the effective amount of the easement being indicated by the distance that the main curve produced backward or forward passes inside of the terminal tangents.

The usefulness of the taper depends on the general maximum running speed of the trains in the several localities, and where speed restrictions result in slow speeds, as for instance either up or down steep mountain grades, the taper is not needed to a very great extent, and in such localities a very short taper is justifiable

if it will save cost of construction versus the cost of construction required by a longer taper.

It is evident that when a train or any part of a train is once on the main curve, the taper has no further effect, and it is no more appropriate to run too fast, for instance on a tapered eight degree curve than on an eight degree curve that is not tapered.

A common form of taper in use, and which was designed and tabulated by the writer in the spring of the year 1881, consists of a series of short curves, each thirty feet long, each successive thirty foot curve being twice as sharp, three times as sharp, four times as sharp, etc., as the first thirty feet of curve used in getting from tangent to the main curve, with the reverse order in getting from the main curve to tangent.

On valley lines, a taper beginning with thirty feet of a fifteen minute curve leaves nothing to be desired for the use of the fastest trains.

On mountain side and similar lines with steep grades and moderate grades, a taper beginning with a two degree and thirty minute curve is found excellent in its results and is justifiably used where a flatter (and longer) taper would involve increased cost of construction.

Too flat a taper and too long a reversing tangent increases cost of construction in a mountain country with steep transverse slopes, or in a confined river gorge where flood water is dangerous and where the mountain sides are steep, to an extent not always fully appreciated.

The effect of the taper and reversing tangent in the increasing of cost of construction is indicated by the resulting distances in a direct line between the centers of the corresponding main curves, versus the sum of the main curve radii, the difference of these distances indicating the horizontal distance to be disposed of in excess of the no-horizontal distance required by reversed curves without tapers and without reversing tangents.

The greatest effect of this sort results from the use of flatter tapers, indicating more benefit with the same expenditure in construction from longer reversing tangents than from flatter tapers, a reversing tangent of one hundred and eighty feet length, however, provides amply for the longest engine and tender now in use, including a suitable length at each end of the reversing

tangent for handling the elevation of the track for the first thirty feet of the taper curve.

In illustration of this matter, two six degree curves with tapers commencing with thirty feet of one degree curve and with one hundred and twenty feet reversing tangent, will have their centers separated by a distance of twenty-one and seven-tenths feet in excess of the sum of their radii; and two six degree curves with tapers commencing with thirty feet of thirty minute curve and with one hundred and twenty feet reversing tangent, will have their centers separated by a distance of sixty-three and one-tenth feet in excess of the sum of their radii, resulting in the latter case in a distance of forty-one and four-tenths feet horizontal to dispose of in the last example in excess of that in the first example, which forty-one and four-tenths feet might result in prohibitive or at least in extravagant cost of construction.

In further illustration of this matter: two ten degree curves with tapers commencing with thirty feet of two degree and thirty minute curve and with one hundred and twenty feet of reversing tangent, will have their centers separated by a distance of twenty-one feet in excess of the sum of their radii; and two ten degree curves with tapers commencing with thirty feet of one degree curve and with one hundred and twenty feet of reversing tangent, will have their centers separated by a distance of seventy-six and five-tenths feet in excess of the sum of their radii; and two ten degree curves with tapers commencing with thirty feet of thirty minute curve and with one hundred and twenty feet of reversing tangent, will have their centers separated by a distance of two hundred and thirty-three and five-tenths feet in excess of the sum of their radii.

These extra horizontal distances to dispose of, for instance in a river gorge, would mean part or all of the distance more than otherwise necessary used in placing the center line of the railroad more into the river flood exposure or more into the mountain sides in cutting or tunneling, and in close localities might give excessive cost of construction without increasing the suitable speed of trains for that locality; all of which indicates the need of conservatism in deciding on the financially appropriate taper curve rate.

The field work of locating a new line should be as accurate

instrumentally, including measurements, as is reasonably practicable, in order to avoid the subsequent cost during construction of erroneous work by the slightly increased cost of the location surveys.

In locating a line on rough country, like a steep mountain side or a river gorge of like character, it is economical to have the preliminary survey made with the same accuracy of measurement and instrumental work as characterizes the final located line.

This is not the universally prevalent practice, which explains to some extent the failures to place the line in its most advantageous position in reference to the topography which are occasionally seen and paid for heavily by the investors, often unconsciously.

Where a finally located line is carefully planned in reference to a preliminary line, and the final line is correctly run out instrumentally, it is certain not to occupy the carefully planned position if the instrumental and measurement work of the preliminary line was not as correct as that of the finally located line; and, if the careful planning was correct, the located line will have to be resurveyed, which may be a considerable cost entirely wasted if the region is precipitous, or heavily overgrown with brush and timber.

Field or field office computations for facilitating the placing of the final center line in reference to a preliminary line should, in steep transverse slope country, be based on working plats of a scale not smaller than fifty feet to the inch, and these plats be considered as diagrams, the final notes for field use being computed therefrom. Any less careful methods in such a region are reckless trifling with the resulting construction expenditure.

Field books, for the use of engineers, designed to furnish ready solutions of the mathematical problems which occur in the field or the field office in locating a line of railroad, are sometimes somewhat circuitous in their methods, which tends to extra expenditure of time that is paid for and to increased liability to error.

All location problems that can present themselves to the engineer, with either the use of plain or of tapered curves, can be solved the most readily and rapidly by referring the centers of the curves to rectangular coordinates, one of which is generally

most suitably an initial or a terminal tangent, the intermediate distances being most conveniently resolved by a corresponding traverse; the final solution of the most complicated problem then taking the shape of the working of a triangle.

When this method is once understood, all other methods become cumbersome and wasteful of time.

The reduction of grade rate on curves on long, continuous, maximum grades is of importance, the ideal condition being that there shall be no more resistance to propulsion on the curve than on the adjacent tangent.

Of the various proposed methods, the writer has found by experiment that the following is satisfactory for all practical purposes:—

Up to and including three degree curve, reduce grade rate thirty-five one-thousandths foot per degree of curve;

Thence to and including six degree curve, reduce grade rate four one-hundredths foot per degree of curve;

Thence to and including eight and one-half degree curve, reduce grade rate forty-five one-thousandths foot per degree of curve;

Thence to and including ten degree curve, reduce grade rate five one-hundredths foot per degree of curve.

A slightly less grade rate reduction will answer the purpose on very perfectly maintained track.

The comparison of alternative lines in reference to their annual operating expenses as affected by distance, grade rate and rise and fall, and curvature, all versus annual interest on their several costs of construction, should be undertaken with extreme conservatism as to predicted immediate traffic and its rate of increase, particularly in these times of passenger and freight automobile competition, as well as the possible competition of additional rail lines that may hereafter be built advisably or otherwise.

It is doubtful if less than twelve percent per annum should be used in capitalizing supposed saving in operating expenses versus more nearly known difference in cost of construction, whereas under conditions of a few years ago a much less annual rate could be safely used for such capitalization; and some items of cost of construction may be exceedingly approximate.

This matter, however, is to be determined for each case.

The well known variety of formulae and methods for approximate determination of differences of cost of operation need not be detailed, but in place of it a description of the method preferred by the writer may be of interest.

If the accounts of an existing line of operated railroad are available, which railroad or some division of it resembles the proposed line in general physical characteristics and probable method of operation, it can be assumed for the purpose in view that the new road will have its manifest freight trains and its passenger trains, etc., of about the same tonnages—but perhaps with a less number of trains of each class—as the existing road. That is, a representative freight and passenger business can be assumed, with the total approximately corresponding to the conservative prediction of the business of the new road for the assumed period, and this representative business can be in the form of a defined number of trains of the sundry classes per day both ways over the road.

It will be noticed that the actual accounts of the existing road that are of interest in this connection should not include general expenses common to all tonnage, but only the direct train expenses as follows:

Locomotive expense, car expense, train crews, maintenance of road exclusive of special accounts like snow sheds, for instance.

Cost of locomotive fuel to have added to it suitable freight, for instance one-half cent per ton mile.

The actual account items of the existing road should first be reduced to their value on equivalent straight and level track by the proper factor for the existing road, which account items can then be multiplied by the proper factor to obtain their supposed value per actual mile of the proposed road.

The reasonably correct determination of these factors is of evident importance, and its importance increases with the amount of difference between the existing and the proposed road as to grade rises and falls and total curvatures.

Also in the present state of railroad records it is practically necessary to use the same factor for freight trains and for passenger trains, that is, a compromise factor, and an attempt to take account of all variations in classes and speeds of

trains would require impracticable calculations and unattainable data.

Assuming, however, an average resistance to propulsion for all classes of trains to be ten pounds to the ton of two thousand pounds, the corresponding up grade would be five-tenths of one percent, one mile of which with twenty-six and four-tenths feet rise would require the same power expenditure for the rise only as would be expended in running the train one mile on straight and level track. That is, the expenditure of power for lifting the train one foot vertical would be the same as for propelling the train on two hundred feet of straight and level track.

Expenditure of power and cost of power (exclusive of enginemen's wages) are not in proportion, the cost ratio being supposedly, all things being included, as about one-quarter to one-fifth of the expenditure ratio. One-fifth of two hundred feet being forty feet, and forty-four feet being conveniently used.

Similarly assuming average curve resistance per degree to be equivalent to that of a grade of forty-five one-thousandths percent, it would be about one-eleventh of the resistance of one foot vertical of grade, or per above assumption, one degree of curvature would be taken as equivalent to four feet horizontal.

Evidently, in fact, the very light curves, thirty minute curves for instance, are probably operated without any extra cost over that of operating the same length of tangent; and similarly, where the ruling grade is, for instance, fairly steep, as one percent more or less, the cost of operating undulations of grades of very light rates is probably little or nothing in excess of operating a corresponding distance of level grade, and the above assumed values of the cost of operating a foot vertical of grade and a degree of curvature are considered as being an average of cost of operating such light grades and curves, and of operating grades and curves the actual cost of operating which may be in excess of the assumed cost figures.

The cost of maintenance of road for passenger trains versus for freight trains is assumed to be per train mile for certain items, and assumed to be per the relation of the squares of the average velocities of freight trains and of passenger trains for other items.

On some roads this relation would be about three, and on

some roads about four for passenger trains to one for freight trains; in both cases per their total tonnage.

Doubtless with increased knowledge derived from more careful segregation of accounts of cost of operation, more minutely accurate factors will be attainable.

The method may be illustrated by the following example:

Actual distance one hundred miles.

1056 degrees curvature at 4 feet		4,224 feet.
3122 feet rise East,		
1102 feet rise West,		
4224 feet divided by two gives average rise on round trip of 2112 feet at 44 feet		92,928 feet.
Total equivalent straight and level feet		97,152 feet.
Which is	18.4 miles.	
Actual distance	100.0 miles.	
Total equivalent straight and level distance	118.4 miles.	

which is 1.184 times the actual distance.

Assume gross trailing load	2000 short tons.
Assume net trailing load	800 short tons.
Assume fuel oil	56 cents per barrel.
Assume fuel oil freight	10.54 cents per barrel.

Assume train hauled by two Consolidation engines with 57-inch drivers and 30-inch stroke, with 22-inch cylinder diameter and 93.5 tons on the driving wheels, with 200 pounds steam pressure in the boiler, and each engine and tender weighing 190.22 short tons.

Table A gives the cost for one train mile.

Similar methods apply to all classes of trains, but if a helper engine is utilized daily, for instance sixty-five miles, and wages are paid for one hundred miles, the engineer and fireman would each receive per mile one hundred sixty-fifths of wage rates in Table A.

It may be of interest to supplement the above with a statement of the difference in cost of hauling the same trailing load with one Mallet compound engine having fifty-seven-inch diameter driving wheels and thirty-inch stroke, with cylinders of twenty-six inches and forty inches diameters and with one hun-

Table A. Cost of One Train Mile with Two Consolidation Locomotives.

Sundry Costs.

	Per Actual Mile.	Per Equivalent Straight and Level Mile.	Multiple.	Additive Constant per Actual Mile.	Total Cost per Actual Mile.
	Cents.	Cents.		Cents.	Cents.
Engineer, road engine	5.350	....	1.0	....	5.350
Engineer, helper engine	5.350	....	1.0	....	5.350
Fireman, road engine	2.970	....	1.0	....	2.970
Fireman, helper engine	2.970	....	1.0	....	2.970
Road engine fuel	....	13.200	1.184	....	15.629
Helper engine fuel	....	13.200	1.184	....	15.629
Road engine fuel freight	....	2.484	1.184	....	2.941
Helper engine fuel freight	....	2.484	1.184	....	2.941
Road engine repairs	....	8.735	1.184	....	10.342
Helper engine repairs	....	8.735	1.184	....	10.342
Road engine lubrication	....	0.440	1.184	....	0.521
Helper engine lubrication	....	0.440	1.184	....	0.521
Road engine roundhouse men, etc.	5.470	....	1.0	....	5.470
Helper engine roundhouse men, etc.	5.470	....	1.0	....	5.470
Train crews	17.731	....	1.0	....	17.731
Car lubrication, oiling, inspection, etc.	....	17.047	1.184	14.547	34.731
Maintenance of road for road engine	....	1.205	1.184	....	1.427
Maintenance of road for helper engine	....	1.205	1.184	....	1.427
Maintenance of road for cars	....	12.676	1.184	2.146	17.154
Total for one train mile					158.916

being for 800 net tons 0.198645 cents per net ton mile.

dred ninety-seven tons on the driving wheels, with two hundred pounds steam pressure in the boiler, and with other conditions the same as before, the engine and tender weighing one hundred thirteen and one-tenth tons. Table B gives cost for one train mile when using one Mallet compound engine.

That is, the use of the Mallet compound engine in place of the two consolidation engines, in this instance,

Saves 20.306 cents per train mile,
" 0.025382 cents per net ton mile,
" 0.006835 cents per gross ton mile,

the gross tons including the engines and tenders.

This equivalent straight and level distance method when applied, for instance, to an operated division of an existing railroad, for the purpose of segregating these direct operating costs of a train to sundry parts of the division, for instance, to the several distances between stations at which the train stops, will give results which added together will equal the actual total of these direct operating expenses of that train over the entire division, regardless of what values may have been assumed for curvature and grade rise and fall.

If so used, however, it would be well to have a factor for passenger trains and a factor for freight trains, corresponding to their respective resistances to propulsion at their several average speeds.

This method of alternative line comparisons, which may be considered as predicting the operation of the road, with an assumed traffic, although necessarily imperfect, can be said to be at least as perfect as the data at hand, and if used conservatively will prevent the injudicious adoption of too expensive a line.

Table B. Cost for One Train Mile with One Mallet Locomotive.

	Sundry Costs. Per Actual Mile. Cents.	Sundry Costs. Per Equivalent Straight and Level Mile. Cents.	Multiple.	Additive Constant per Actual Mile. Cents.	Total Cost per Actual Mile. Cents.
Engineer, road engine	6.350	....	1.0	....	6.350
Fireman, road engine	4.000	....	1.0	....	4.000
Road engine fuel	....	22.008	1.184	....	26.057
Road engine fuel freight	....	4.142	1.184	....	4.904
Road engine repairs	....	15.286	1.184	....	18.099
Road engine lubrication	....	1.010	1.184	....	1.196
Road engine roundhouse men, etc.	6.078	....	1.0	....	6.078
Train crews	17.731	....	1.0	....	17.731
Car lubrication, oiling, inspection, etc.	....	17.047	1.184	14.547	34.731
Maintenance of road for engine	....	1.951	1.184	....	2.310
Maintenance of road for cars	....	12.676	1.184	2.146	17.154
Total for one train mile					138.610

being for 800 net tons 0.173263 cents per net ton mile.

DISCUSSION

Mr. Hood. **Mr. William Hood,** in answer to a question by Mr. Wm. J. Ryan as to whether the rate of compensation should be different for short and long trains and for passenger and freight lines, said the old theory was that there should be less compensation for short trains than for long trains; also that compensation is practically adjusted on the basis of long trains, on the possibility that sometime long trains would be operated. The rates of compensation given in the paper were those which he had established in 1875. Experiments later made in Belgium indicated a somewhat greater rate of reduction than he used, due, probably, to the more rigid rolling stock in use there. After building many miles of line, using his rates, a series of experiments showed that the sharper curves pulled a little more easily than the tangents or the easier curves.

Mr. Eaton. **Mr. G. M. Eaton,*** Mem. A. I. E. E., said that in locating a main trunk line to be operated electrically, some modification may be made:

(1) Heavy locomotives of shorter wheel base may be used. Therefore, it will be possible to use somewhat sharper curves than on steam roads.

(2) The grade may be increased considerably for short distances, due to the great overload capacity of electric locomotives, for a short time.

(3) The curve compensation may be somewhat decreased when the regeneration of current is considered.

Mr. Hood. **Mr. William Hood,** in closing, said that, referring to the remarks of Mr. G. M. Eaton concerning modifications of grades and curves for main trunk lines to be built for electrical operation, he would quote and answer as follows:

"(1) Heavy locomotives of shorter wheel base may be used. Therefore, it will be possible to use somewhat sharper curves than on steam roads."

Suitable speed limitations on curves are independent of the kind of locomotives used.

"(2) The grade may be increased considerably for short distances due to the great overload capacity of electric locomotives, for a short time."

Electric locomotives and trains, as well as steam locomotives and trains, will run more satisfactorily on a road without occasional unduly steep short grades, and economy in road construction can be attained by suitable skill in other directions than severe grade chopping.

"(3) The curve compensation may be somewhat decreased when the regeneration of current is considered."

It seems not advisable to in effect steepen grades locally against up grade trains for the purpose of increasing the gravity effect on down grade trains.

In general it seems best to build a main trunk line as well for electrical operation as for steam operation.

* Eng. Ry. Division, Westinghouse Elect. & Mfg. Co., East Pittsburgh, Pa.

Paper No. 80

THE LOCATING OF A NEW LINE.

By

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The actual work and methods of locating a new railway are so much dependent upon the type of line which it is proposed to build, and this, in turn, is so much modified by the physical character of the country and by its industrial history and development, that it seems advisable to examine these matters at the outset.

South Africa is a plateau rising, as far as railway development has gone, to a height of 5735 feet, that being the altitude of Johannesburg, the greatest industrial centre in the subcontinent. Lines from five ports concentrate at this point. Four of these ports are within the South African Union; the fifth, Delagoa Bay, being in Portuguese territory. All these lines of railway encounter rough and steep country at short distances from the Coast. None of them, with the exception of perhaps the Delagoa Bay line, were planned as Main Lines to develop important inland mining and agricultural areas. They were designed to meet the requirements of small pastoral communities living at no great distance from these ports, and afterwards extended great distances inland on the discovery of diamonds and gold.

The main obstacles which the country presents to railway development were encountered in these short lines, and had to be dealt with at a time when neither the development nor the prospects of the country had made it possible or desirable to spend the capital necessary to carry out heavy works. The gauge of 3 ft. 6 in., to which all South African lines of importance are built, was decided on at this stage. This gauge was

very suitable at that time, but if the pioneer lines had been built to be extended over long distances of comparatively easy country and to carry a large traffic, then it is possible that a wider gauge would have been justified. Large sums are being spent in reducing grades and in reducing and flattening curvature, but the question of a wider gauge has so far not been seriously raised. Sharp curves and steep grades were freely used on all the lines, and were necessary in order to negotiate the narrow kloofs and steep ascents. The Natal Main Line, for instance, on which alone is now carried over three and a half million tons per annum on a single line, has a minimum curvature of 300 ft. radius and grade of 1 in 30. The grades are not compensated for curvature, and, as the limits of grade and curvature are freely used together, the virtual grade is not better than 1 in 25. The line rises to a height of 2225 feet in the first 28 miles. It has on this section approximately 375 degrees of curvature to the mile. Sixty trains now pass over this line daily.

The principal problem to be faced by the locating engineer in South Africa is that of grades. There are problems on the Coast belt, of lagoons, blown sand, corrosion and washaways; and inland, of waterless plains and great distances; but the question of grade has been the main consideration in the working of South African railways.

It will therefore be instructive to consider the various methods that have been adopted for overcoming heights. These methods have been, at the different stages of railway development, (1) steep grades, (2) reversing stations or zigzags, (3) artificial development, and (4) heavy work, with or without the assistance of artificial development.

The early engineers had no option but to introduce steep grades, as the worst problems had to be solved in some way at a time when the resources of the country were undeveloped or undiscovered. The steepest grade adopted was 1 in 30, uncompensated, that being a grade which is practicable almost anywhere, although a rack section (which has since been replaced by a 1 in 50 grade) was introduced on the Delagoa Bay line, and reversing stations in conjunction with 1 in 30 grades were used in ascending van Reenen's Pass on the Drakensberg. Reversing stations were used as a means of getting

a 1 in 50 grade on the northern section of the Natal main line. These are a cheap and ready method of getting over grade difficulties in the first instance, but are expensive to operate, and are a serious cause of delay if heavy traffic is afterwards developed. The question of replacing those referred to is under consideration, and even for unimportant branch lines, reversing stations are out of favour, and recent examples are not likely to be repeated.

The next stage in the development of the art of laying out easy grades on steeply rising country has been artificial development, and South Africa has many interesting and picturesque examples of this method. The engineer in difficulties is constantly on the look-out for a likely spot where he can go through a nek with a cutting and, circling round the shoulder of a hill, reverse his direction. Then he will probably find a point at the junction of two or more valleys, where, by crossing the tributary streams, and re-crossing the main stream by a high bridge, he regains his original direction at a much lower level. This method is still in use even for main line work, and although it necessarily introduces a large amount of curvature, it is difficult to see how some of the ascents can be gained otherwise. An extensive deviation of the Natal main line which is at present being constructed furnishes an interesting example of crossing a summit on a comparatively easy grade by means of artificial development, combined with heavy works. The deviation commences at Pietermaritzburg station yard, and the obstacle to be surmounted is a ridge 1518 feet above the starting point. The only practicable point of crossing the ridge is less than six miles from the starting point, in a direct line. It was practicable to reduce the summit only 134 feet by means of a tunnel 902 yards long. Starting from the grade at the mouth of the proposed tunnel, natural development failed to reach the station yard by some 250 feet in elevation. The grade and the two ends of the line being fixed, either absolutely or by practical considerations, it was necessary to have recourse to artificial development. This was done on curves of 7½ chains radius (495 feet radius; or approximately 11.5°) at the cost of heavy work. There is no slack grade, except for crossing stations; the located line being 14¾ miles in length. In addition to tun-

nelling, it is estimated that the earthwork will be in excess of 75,000 cubic yards per mile, for a single line. Artificial development in this case introduced at least 300 degrees of curvature, all on the limit grade. As at least 40 heavy trains per day will be run over this line; £30 per degree is quite a moderate amount to which to equate curvature. For this class of line the method adopted should be used only as a last resort. As the improvement of this particular part of the Natal main line has been under consideration for some 20 years, and as at least four routes have been carefully surveyed, it may be taken that a direct line was unobtainable.

While artificial development is exceptional and undesirable on main line work on account of the amount of curvature of necessarily small radius introduced, for branch lines it may be said to be the normal method of locating fairly flat grades, a grade of 1 in 40 being the steepest now favoured for branch line work. For this class of work the limiting radius of curvature is 5 chains (330 feet; 100.6 metres). It is comparatively easy to develop length with this limit of curvature. The steepest grade now being used for the main lines is 1 in 50, but that is used only with the greatest reluctance, the standard which is aimed at being 1 in 66 as a maximum. For instance, surveys are now in progress to relocate the first section of the Natal main line from Durban, which, after various reverse grades, reaches the first step in the plateau at a height of 2500 feet, and in a length of some 40 miles. The grade on the present line is 1 in 30, against both "up" and "down" traffic, uncompensated on curves of 300 feet radius, there being approximately 370 degrees of curvature per mile. The new location will be on a 1 in 66 grade compensated, with no reverse grades. Curvature will be reduced by about half, and the length will not be increased. Final estimates of the cost have not been completed, but it is not misleading to say that the cost will be approximately £20,000 per mile for a single line. This is a direct line, the gradient being attained without artificial development. Tunnels up to about half a mile in length, but mostly much shorter, are being introduced to cut through the sharp spurs, instead of the old system of going round on sharp curves.

The old line and the new location are instructive examples

of the earliest and latest stages of the progress of railway location in South Africa.

Having, in the foregoing, glanced at the physical and economical conditions that have influenced the development of railway construction in South Africa, and having indicated the standard which has been attained in main and branch lines in the more difficult parts of the country, it is now proposed to examine the considerations by which the locating engineer is guided in the selection of a route and in deciding in detail questions of grade curvature, rise and fall, length, etc.

In these matters the principles laid down by Wellington in "The Economic Theory of Railway Location" are followed, with due regard to local conditions, and American engineers will find nothing new in South African practice.

Grades being the great difficulty in South Africa, the first consideration is to get the best practicable grade. In this respect, it is very easy to compare different schemes, the only difficulty being in anticipating the growth of traffic. South African railway managers have had many surprises in this respect in the past. A few years ago the problem in Natal was to carry imported goods to the gold mining areas, and grades against traffic moving inland were being improved to facilitate this work. Now the problem is to carry coal to the port, and empties back to the coal fields, the traffic to the mines being relatively unimportant, and it is found to be imperative to build practically a new line.

After grades, curvature is the greatest consideration. Curvature on the pioneer lines is extremely heavy, averaging as much as 370 degrees over the worst sections. As usually happens, the sharpest curves are associated with the heaviest grades. The difficulty of grades has been overcome to some extent by the introduction of exceptionally heavy engines, designed to run on curves of 300 feet radius (19 degrees) on the 3 ft. 6 in. gauge. The South African Railways Class 12 engines, which have proved most successful, weigh 91 tons 16 cwt. without the tender, and it has been claimed that they are the heaviest non-articulated engines working on such a narrow gauge. Under these circumstances, the difficulties arising from curvature, especially sharp curvature, on steep grades, become

accentuated, and the wear on rails and tires becomes very great, in some situations an 80-lb. rail lasting only about six months. For new work where curves and grades are more favourable, it is considered that the expenditure due to curvature is about eight pence per degree per annum multiplied by the number of trains run over the section per day. The justifiable expenditure to avoid curvature is, on the most important lines taken at as much as £25 per degree. The cost per train mile on the South African Government railways is appproximately 5/11.

In a country presenting the physical characteristics of South Africa the question of rise and fall is most important. This especially applies, however, to a comparison between two routes of considerable length, but it is seldom that the locating engineer has the luxury of selecting such a route on purely engineering principles. A great many other considerations have weight in this, as in other countries, and rightly so. It is therefore difficult to define South African practice with regard to rise and fall on a large scale. On any particular route, the question of saving rise and fall is seldom of relative importance. for the reason that so little can be done by heavy works to shorten the long inclines which are a feature of the country. For minor rise and fall the average practice is to allow 12/- per foot per daily train (round trip) but grades would not be broken up for the sake of strictly observing this rule.

The question of length is the only remaining consideration. In main line work, length is in every case sacrificed to grade, at least to the extent of getting a 1 in 66 grade on main lines and 1 in 40 on branch lines. An important deviation recently completed on the Natal main line cuts out a section 21 miles in length having 1 in 30 uncompensated grades in each direction. On the new line the maximum grade is 1 in 65 compensated. but the length is 28 miles. Within the prescribed limits of grade, however, the question of length is most carefully studied and on important lines it has been considered justifiable to expend as much at £3 per foot to effect minor shortening. It sometimes happens however, especially on a single line, such as practically all South African lines are, that circumstances do not justify expenditure proportionate to this. It is often

difficult in broken country to locate crossing stations to suit the traffic. If heavy expenditure can be avoided by lengthening a section which is less than the average between crossing stations, the question should be carefully considered on its merits, as a considerable lengthening might be introduced without appreciably delaying the traffic.

The methods adopted in the field by the locating engineer do not present any novel features. In the settled districts, a map to the scale of one inch to the mile, shewing farm boundaries and the principal streams, is generally obtainable. In the first reconnaissance, if the route is of any considerable length, an aneroid barometer is used to ascertain the altitude of tying points. The next step is to run between these points with an Abney level to ascertain whether the limit grade is practicable. The length can be roughly ascertained by sketching on the map and from local information. Should grade difficulties present themselves a rough tacheometer survey is run and plotted. This, with field notes, will enable the length, curvature, etc., to be roughly estimated; or some salient points may be fixed from each station, and a rough contour plan prepared. If satisfactory results are obtained, a detailed tacheometer survey is made and a contour plan prepared to convenient scale, of, say, 200 feet to the inch in moderate country, and 100 feet to the inch in broken country. On this, trial lines are located and sections plotted, and the locating engineer carefully balances the elements of safety, cost, curvature, length, etc. It may be said that it has been found in South Africa, as elsewhere, that it is often not so much a question of balancing curvature against cost, as of eliminating a fair portion of it altogether by extra care and the help of a good contour plan.

When the route has been decided upon the line is staked out and a plan section and cross sections plotted. Should the country be broken, the final location of the line is done from the cross sections and the line is, where necessary, re-pegged. The 66-foot chain, divided into 100 links, is the unit of measurement in use over nearly all South African railways, and curves are defined in terms of the radius in chains, while grades are given in ratios. This necessitates the preparation and use of a great many tables and leads to many calculations that might

be dispensed with by the use of a more rational system of units, but in practice the inconvenience is not so much felt as might be supposed. All curves are located with transition curves at the ends, generally three chains long, and grades are connected by vertical curves at least four chains long. Grades are compensated for curvature at the rate of from 0.035 to 0.05 per cent per degree of curvature. A compensation of 0.04 is found, generally, to be sufficient, if not rather excessive, on new rails, but there is an impression that for long trains extending over perhaps more than one curve the resistance due to curvature increases. On sharp curves check railing adds to the resistance. The condition of the rails and tires and the length of rigid wheel base are important elements. The tendency therefore is to increase the compensation to 0.05 where possible.

The foregoing refers to the practice of locating standard 3 ft. 6 in. gauge main and branch lines in the more difficult parts of the country. Although South Africa is not by any means a regular plateau, the difficulties decrease inland and there are extensive areas presenting no particular obstacles. On the other hand, there are parts near the Coast which cannot be economically developed by means of a 3 ft. 6 in. gauge railway with a limiting radius of curvature of 300 feet (91.4 m.; 19°). A two-foot gauge has, consequently, been introduced, with a minimum radius of curvature of 175 feet (53.3 m.; 32.75°). There are 474 miles of railway of this gauge within the Union, and in German Southwest Africa there is a line over 360 miles in length on a gauge of 23.6 inches (0.6 metre), with a minimum radius of curvature of 38.26 metres. This line rises to a height of 5370 feet. These lines serve their purpose, but owing to the delay and cost of trans-shipping they are not looked upon with favour. At the present time, although some existing lines are being extended, there is no proposal within the Union to build new lines, and any proposal in future to depart from the standard gauge of 3 ft. 6 in. will be most carefully scrutinised before being adopted.

DISCUSSION

Mr. William Hood,* M. Am. Soc. C. E., in response to a request from Mr. A. H. Babcock that he give his views with reference to the location of a line for electrical operation, said that if a new road is to be built to be operated exclusively by electric power, and it is certain that it will never be operated by steam, in whole or in part, it is quite correct to build for exclusive electrical operation; that it is not uncommon to build for both kinds of motive power, owing to the uncertainty involved; and that in his opinion it would be injudicious to tie a railroad up to unnecessarily sharp curves and steep grades if a better line is available at small additional cost. A railroad built for steam power may be well operated by electricity. In general, he would not favor short pieces of unnecessarily sharp curvature and steep grade, unless it were absolutely certain that the line would always be operated by electricity. Mr. Hood.

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Paper No. 81

CONSTRUCTION METHODS AND EQUIPMENT OF RAILWAYS.

By

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The operations involved in the construction of railways have always required the employment of large numbers of men, the majority of whom constitute what is known as unskilled labor, in contra-distinction to the various classes of mechanics ordinarily called skilled labor.

Due to the decrease in the amount of available unskilled labor and the great decrease in the efficiency of that available, the increase in labor-saving devices and appliances for railroad construction work has been rapid during the past twenty-five years; but due also to the physical conditions entering into construction of this kind, methods which would be entirely suitable for one piece of work would not be at all adaptable for other work in many ways similar, and the result has been a great diversity of such labor-saving appliances in an attempt to meet the various conditions.

Railroad construction divides itself into the following principal classes of work:—

1. Clearing of trees and underbrush and the grubbing out of roots.

2. The excavation and transportation of earth and rock to form the roadbed.

3. Tunnels.

4. Construction of bridges, which has the following subheads:—

    (a) Timber bridges.

    (b) Concrete and masonry bridges.

(c) Culverts of metal or earthenware pipes.
(d) Steel superstructures of bridges.

5. Tracklaying.
6. Ballasting.
7. Structures, such as stations, water stations, shops, etc.

CLEARING AND GRUBBING.

The work included under the first division mentioned above, ordinarily spoken of as "Clearing and Grubbing", is carried on today in much the same manner as it has been for many years past, except that the lack of efficiency in the labor available for this work is particularly noticeable. The hardy axemen found in such great numbers in this country a quarter of a century ago are fast disappearing, and the axe in the hands of the foreign laborer is not an effective tool. The writer has seen many railroad clearings that looked more as if the trees had been gnawed down by beavers than felled by axes.

So far as the grubbing is concerned, there are a number of stump-pulling appliances, which together with the traction engine, which has developed rapidly in recent years, and the explosives now manufactured for the purpose, have enabled this work to be done more effectively and cheaply.

EXCAVATION.

It is under the second classification of work, viz., Excavation, that probably the greatest development of construction appliances has been made. The work of excavation, using the word in its broad sense, includes the loosening of the material, the loading of same into a means of conveyance, conveying to the place of deposit, and depositing in place.

The first of these operations, that is, the loosening of the material, depends primarily upon the character of the material to be handled, and to some extent on the means of conveyance to be used and the disposal. In the construction of railroads, materials of all degrees of hardness and toughness are encountered, and it is sometimes necessary to deposit material in a position where it must resist the action of water, and where larger pieces of rock are required; or again, it may be deposited in a low embankment where the larger pieces of rock can not

be used. All of these conditions, as above stated, affect the manner in which the work must be done.

Of the various methods in use, the following are probably representative:— the pick, the plow, drills and explosives.

Under the latter heading come some of the most interesting and valuable advances and improvements to be found in the development of this art. The blasting of rock has been known and practiced for several centuries, but since the invention of dynamite this work has been carried on in an entirely different manner and to far greater effect.

The drill has progressed from the old hammer and steel and churn drill to the highly effective air drill of today, carrying with it a corresponding increase in capacity for the removal of rock at very much less cost.

There has also been adapted to the removal of rock on railroads, during the past few years, the well drill, by which large and deep holes are drilled throughout the excavation to be made, and large sections of it so loosened by the simultaneous shooting of a number of these holes that steam shovels are enabled to work continuously for long periods before it is necessary to do further blasting, thus obviating the moving back of the shovel and other equipment before each shot is made, as is necessary where only the face immediately ahead of the shovel is shot.

The second of these operations, viz., loading, has also shown many interesting developments. In much of the railroad construction carried on today, the material is loaded into the means of conveyance by men with shovels, after having been loosened with the pick, if necessary, in the same manner as has been done since the early days of railroad construction.

Likewise, much railroad work is done by teams and scrapers, of which there are a number of kinds. Those commonly in use are the drag scraper and fresno for short hauls, and wheel scrapers for the longer hauls, the material being loaded by dragging the pan of the scraper through the material, which has previously been loosened by a plow, if necessary.

Of the above mentioned, the fresno is the latest development and is almost wholly taking the place of the drag scraper.

Hauls in excess of eight hundred (800) to one thousand (1,000) feet can not be made economically with a wheel scraper. Formerly, where long hauls were necessary, much of this work was done by hand loading into wagons or small cars.

In certain classes of material the elevating grader is used for loading into wagons. This consists of a plow which turns its furrow onto an elevating belt, which in turn deposits the material in wagons driven alongside. The grader is propelled by either horses or traction engine. The elevating grader furnishes a means of doing work very cheaply, where conditions are suitable. The material to be handled must be such, however, that it can be carried over the belt, and in stony or very sandy ground this is not practicable. Many miles of the Western prairie railroads in this country have been constructed by the use of graders depositing direct in the embankment from long borrow pits on either side of the line of railway.

Where the amount of work to be done is sufficient, and justifies its installation, the steam shovel furnishes in many cases the best and most satisfactory method of loading material. It has the advantage of being adapted to handle either earth or blasted rock, and the roots and stumps of trees do not interfere with its operation, as in the case of team or hand work. In fact, it is not necessary to grub out the stumps ahead of the shovel on work which is being done by this method.

Material from the steam shovel is usually loaded into cars and hauled by locomotives to the place of deposit. The development of the steam shovel has been in the direction of capacity rather than change in type, and there are found on railroad work today shovels weighing from 20 tons to 110 tons.

The so-called drag-line, which is primarily adapted to the handling of material where the points of deposit and of excavation are both within reach of the machine, is now being used to some extent in the loading of cars and wagons, and to that extent is taking the place of the steam shovel, its particular advantage being that it can dig much below the grade on which the machine travels, which is a great advantage, particularly if the material is wet and the ground soft and swampy.

There are several types of drag-line machines, the basis of all of them being a heavy steel bucket which is carried forward

either from the boom or cableway and drawn back through the material to be handled, during which operation it loads itself, and then is raised and carried to the point of deposit and there automatically dumped. Where conditions are favorable, material can probably be handled more cheaply by this method than by any other method in use today.

The operation of conveying is accomplished in various ways. It is to meet the requirements of economy in this operation that developments have been made not only in it, but in all of the other operations involved in excavation.

In the old days when much railroad embankment was made by men using wheelbarrows, it was good practice to continue their use only so long as the time, and consequently the cost, of transporting from the pit to the dump and returning did not exceed that of loading, which in practice limited the distance earth could economically be moved by this method to about one hundred and fifty (150) feet. If the distance was greater, some other method was resorted to, the cost of transporting necessitating the change.

The cost of transporting is often reduced by increasing the capacity of the conveying medium, which in turn has required new and improved means for loading the larger conveying mediums, and in very many other ways can be seen the far-reaching influence of this operation for a general development throughout the whole field.

Where scrapers are used, the scraper with its load is drawn by horses to the point of deposit and there dumped. Likewise, where elevating grader and wagons are used, conveying is accomplished in the same way. Where steam shovels are used, conveying may be done by wagons if the haul is short, but it is ordinarily accomplished by the use of cars and locomotives. The track for these cars may be either narrow gauge (3 ft.) or standard gauge (4 ft. 8½ in.), the determining condition as to the gauge used being, first, the amount of work to be performed at any particular point by the plant, and second, the accessibility of same from an existing railroad or other means of transportation. The large, heavy cars and locomotives required for standard-gauge work are moved only with considerable difficulty through a rough country.

The operation of depositing the material, in the case of work in which teams and scrapers and wagons are used, is the simple one of dumping the material and leveling off same by men with shovels. Where material from steam shovel is being deposited in railroad embankments, if the height of the embankment is more than four (4) or five (5) feet, it is necessary, in order to avoid continually raising the track, to build trestles or other means of support for the track on which the material is brought to the dump. Such trestles are constructed generally strong enough to support only empty cars, the end of the fill being maintained at grade to furnish support to the locomotive and loaded cars which are dumped as they pass over the end of the fill.

Where the 3-foot-gauge cars are used, the dumping is accomplished by tipping the car sideways by hand and allowing the material to run out. This is also the case with the smaller cars up to a capacity of, say, six (6) or seven (7) yards, where standard-gauge cars are used; but there are also cars having capacities up to thirty (30) yards used on standard-gauge work where the dumping is accomplished by the use of compressed air furnished from the locomotives.

Cars of this capacity are not generally used on new construction work, being more often used for the filling in of trestles and otherwise improving existing lines of railway, and are largely taking the place of the flat cars and plow, which were much used formerly for this purpose.

After the dumping of the cars, a certain amount of spreading is necessary, which is generally done by men, in case narrow-gauge plant is used; on heavier work, where larger amounts of material are being used on standard-gauge work, the spreader is often used for this purpose. The spreader consists of a heavily weighted car having adjustable wings on either side, which in passing over the track, levels off and spreads the freshly deposited material by means of these outspreading wings. Spreaders are now to be had in which the adjustments are entirely actuated by compressed air.

As a substitute for temporary trestles on very high and short fills, there has in recent years been used a type of cableway bridge, which has proved of considerable economy.

While on the subject of excavation, it is proper to mention two other interesting methods by which this work has been accomplished within the past few years: these are the construction of railroad embankment by use of the hydraulic dredge, as instanced by work done by one of the railroads of this country which skirts the bank of the Mississippi River, and also by the so-called hydraulic sluicing method, which was used by one of our Western railroads.

TUNNELS.

The history of tunnelling is most interesting, extending as it does from the most ancient times, when the work was carried on by barring and wedging and by fire and water, used alternately to heat and quench the rock, down through the seventeenth century, when the introduction of gun powder entirely changed the method of doing this work. The amount and character of work done under the old methods are amazing. The great development came, as in the case of the rock excavation mentioned above, with the invention of dynamite and the improvement of drilling machinery; and while the study of the different methods used in this country and abroad for the driving of tunnels, and also of the different types of drilling and other machinery, would be most interesting, it can not be undertaken here, it being sufficient for the purpose of this paper to briefly mention some of them.

The determination of the method to be followed in the driving of a tunnel always involves the questions of progress and cost, such a method being adopted as will give the maximum of the former consistent with a reasonable cost, all things being considered. This does not necessarily mean that the above mentioned maxima and minima are absolute; but rather, having assumed a certain justifiable cost, the method must be such as to produce a maximum of progress, and vice versa.

The points at which work may be carried on in driving a tunnel are obviously limited by economy. Generally speaking, the two ends of a tunnel are accessible for this purpose at reasonable expense. To afford additional working faces, shafts must be sunk, and the problem of how many, if any, are justified, must be solved.

If the tunnel in question is the critical part, as regards time, in the construction of some large project, the cost of several shafts and the adoption of rapid but expensive methods of tunnel driving may be justified.

In the driving of any railroad tunnel, or other tunnel of large cross section, through rock, the work is carried on by first driving a drift or tunnel of smaller cross section, called a heading, somewhere within the cross section of the finished tunnel. The purpose of this is to facilitate the excavation of the remaining part of the cross section of the tunnel by affording two free faces to the rock which is to be removed, which greatly increases the effectiveness of the explosive.

The size and shape of the heading should be such as to permit a maximum of progress and leave the remaining cross section in the best shape for its removal. The location also should be such as to permit the easiest removal of the remaining cross section. To a considerable extent, the location depends upon the character of the rock, a bottom heading is often the best where the rock is self-supporting, and a top heading where the rock requires timbering for support.

It will be evident that the driving of a heading, with its constricted working space, does not admit the use of labor-saving appliances for handling the material, and is entirely a question, except as to the use of drilling machinery, of hand labor. It will also be evident that the progress of the whole tunnel is entirely dependent upon the progress in the heading.

In European practice where the greatest records of progress have been made, they have been accomplished by driving two, or even more, headings connected by cross drifts to facilitate the removal of the material and ventilation. Due to the relatively low cost of labor in Europe, this has been done without increasing the cost of the whole tunnel excessively.

In the United States, however, these methods have not been generally followed, a single heading usually being driven, with consequently slower progress.

It is in the removal of the remaining cross section of the tunnel, after the heading has been driven, that labor-saving appliances have been developed, principal among which is the

application of the steam shovel operated by compressed air for the loading of blasted material into cars.

There have also been constructed for work of this kind, drill carriages mounted on cars which, in turn, are carried on a track, and which permit the removal of the whole battery of drills before each shot is made, and the replacing of same, as a unit, as soon as the muck has been sufficiently cleared away to permit.

Machines of this kind have also been combined with loading devices, consisting of belt conveyors onto which the blasted material is shovelled by men and conveyed automatically into cars, which in turn are hauled away by either horses or electric locomotives.

During the last few years there have been brought out a number of so-called tunnelling machines, the general principle of which has been a large reciprocating, and at the same time revolving, cutter-head so mounted on a track as to be brought into contact with the face of the rock, which is gradually broken down by blows of the cutter-head, the pulverized material being either washed back by flow of water or carried back by a system of conveying belts. These machines have all been, however, in the nature of an experiment and have not been brought to a state of development where they may be considered of practical use.

In and around New York City during the past decade, there has been carried on a very large amount of sub-aqueous railroad tunnel construction, in the doing of which there have been developed many interesting applications of compressed air, special designs of shields and grouting machines, and other devices for handling the excavated material and cast-iron plates and concrete with which these tunnels have been lined.

BRIDGES.

The trend of bridge construction of American railroads is altogether toward the construction of permanent structures. With the great increase in use of concrete for this purpose, and the decreasing timber supply of this country, there are comparatively few timber bridges now being constructed. What few frame timber bridges are built are in inaccessible places

where it is out of the question, within the limits of economy, to bring in steel or other material, and where suitable timber is abundant on the ground.

There is, of course, still being constructed a considerable amount of timber trestle work, and outside of the approved appliances for driving piles and the pneumatic and electric hand drills for drilling holes for drift bolts, there has been little development in labor-saving appliances in this work.

The enormously increasing use of concrete for railroad structures has practically revolutionized the branches of railroad construction in which it has been used. Aggregates for concrete are far more generally and cheaply obtainable than stone for masonry, and concrete does not require the skilled labor necessary for the construction of masonry structures; and by the combination of concrete and steel, to form so-called "reinforced concrete", the actual quantity of concrete required in many structures is far less than would have been required if they had been constructed of masonry.

The developments in the art of making and placing concrete and appliances for same have been many and of varied kinds.

Portland cement has practically entirely taken the place of natural cement, which was formerly largely used. Many types of concrete mixers have been put in the field, of which there are a large number which are entirely practical and economical of operation. Likewise, various types of dumping buckets for handling the concrete have been devised; and during the last few years a considerable amount of concrete has been handled from the mixer to the structure by elevating it in a tower and dumping it into a chute, through which it flows to the place of deposit.

For the smaller drainage openings on railroads, cast iron pipe is probably principally used. Both vitrified earthenware pipe and pipes of reinforced concrete are used to some extent; the latter shows an increasing use.

The increase in locomotive and train loads has required increase in the capacity of railroad bridges; and the developments in bridge-shop practice and equipment, erecting machin-

ery of increased capacity and field-riveting appliances have all influenced the changes in bridge design.

Plate-girder bridges are replacing truss spans up to one hundred (100) feet or more in length; and there is a growing tendency to use riveted bridges for spans up to one hundred and fifty (150) feet or more, the considerations being greater rigidity and economy, and being made possible by power field-riveting machinery and more effective and powerful erecting appliances.

The use of concrete in connection with steel spans, as for floors or protection to members, should also be noted.

TRACKLAYING.

Economical and rapid tracklaying is dependent upon having at all times a supply of the necessary materials, including rails and ties, delivered on approximately the location where they are to be used.

In prairie country where teams can be used for the purpose of distributing this material, the distribution is accomplished in that way; but in country where it is impossible to distribute by teams, some other method must be devised.

Where the amount of track to be laid is small, the work is usually done from a work train and rail car, handling the material from the work train by hand. To facilitate this handling, where long stretches of track are to be laid, there have been devised tracklaying machines. The general principle of them all is to furnish a means of conveying the ties and rails ahead of the work train, depositing them approximately at the point where they are to be used.

Generally only one half the number of ties are carried forward and bridles are used to hold the track to gauge while the work train passes over, after which the remaining half of the ties are put in place and the track is spiked. By this method a well organized crew should easily lay two (2) miles of track per day.

BALLASTING.

Ballasting, where done on a large scale, is accomplished by the use of bottom-dump cars for depositing the ballast

alongside or between the rails, after which the track is raised with jacks and the material tamped under the ties by hand.

STRUCTURES.

As in the case of bridges, concrete has entered very largely into the field of miscellaneous railroad structures, such as stations, water stations, shops, etc.

In many cases, the smaller structures are made as a monolith at some central plant, loaded onto cars and shipped to the place where they are to be used. This particularly applies to the switchmen's houses and similar small structures.

Some very interesting water stations, including the tanks, have been constructed of concrete, and as above stated, where permanent structures of this character are to be built, concrete is very generally used.

SUMMARY.

In reviewing the whole field of the development in railroad construction methods and equipment, it is probable that the increasing use of concrete would stand first, after which would come the development of the modern explosive as a means for easily and cheaply facilitating the movement of the large volumes of earth, rock and other material necessary for the construction of our railroads.

DISCUSSION

Mr. W. J. Ryan*, Assoc. M. Am. Soc. C. E., stated that on the Northern Pacific Railroad at Mandan, South Dakota, a drag-line fill about 1.5 miles long was built in the autumn and was not brought to grade till the following spring. The material was quite wet when deposited, and the freezing and thawing in this interval of time settled it well. He felt that had they attempted to bring the fill to grade when it was new, it would have been unsatisfactory, because usually a drag-line fill is very loose. Mr. Ryan.

He added that the material was placed in the fill for 6 cents a yard for actual labor costs after the plant was installed; while steam-shovel work in the same locality was costing 10 or 12 cents per yard for labor.

Mr. William Hood,** M. Am. Soc. C. E., said that his experience with drag-line scrapers has been exclusively where, owing to the swampy Mr. Hood.

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Mr. Hood. nature of the ground, it has been impossible to do the work otherwise than with a drag-line scraper or with a very long haul and dumping from trestles. In such a situation, as between the two methods, the drag-line scraper is, of course, very economical.

Mr. Loweth. **Mr. C. F. Loweth,** *** M. Am. Soc. C. E., said that he had found cableways for the construction of fills economical but not rapid. In South Dakota, the Chicago, Milwaukee & St. Paul Ry. had built a fill 5 miles long and from 5 to 35 feet high, rapidly and economically, with several drag lines; but the fill settled slowly and unevenly, and looked rough and unfinished from the start and does still. The temptation was always to make the berm less than it should have been.

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Paper No. 82

RAILWAY CONSTRUCTION METHODS AND EQUIPMENT IN AUSTRALIA.

By

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Ninety-eight per cent of the railways in Australia are owned by the Governments of the States and Commonwealth, and a similar percentage of the construction in progress is being carried out by the same public authorities.

The railways of Australia on June 30, 1914, had a total mileage opened for traffic, as follows:

	Length		Standard Gauge	
	Miles	Kilometres	Feet	Metres
Commonwealth	623	1,002	4′ 8½″ and 3′ 6″	1.43508 and 1.06678
States.				
New South Wales	3,967	6,384	4′ 8½″	1.43508
Victoria	3,835	6,172	5′ 3″	1.60017
Queensland	4,570	7,355	3′ 6″	1.06678
South Australia	1,845	2,969	5′ 3″ and 3′ 6″	1.60017 and 1.06678
Western Australia	2,967	4,775	3′ 6″	1.06678
Tasmania	519	835	3′ 6″	1.06678
Total	18,326	29,492		

The small mileage of private railways is almost wholly connected with mines and sawmills.

At present there are about 3,400 miles of railways (5,474 kilometres) under construction, including about 1,150 miles (1,851 kilometres) which are being built by the Commonwealth Government.

Railway construction proposals in populated parts are usually originated by local agitation, but many large schemes which open up new country are initiated by the Governments. Government railway projects are reported on by Stand-

ing Committees of Parliament after hearing evidence and obtaining expert reports as to first cost, probable revenue, and operating expenses.

In the survey of new lines, the principles of railway location as worked out in America are applied. Short momentum grades, and temporary steep grades are used on difficult sections, and the lines are regraded when the development of traffic justifies the cost. The original location and grading are done with this in view.

Incidentally, it may be worth while to mention that the acquisition of the land required for building railways is, in all the States except Victoria, carried out by the Constructing Authority, and the cost is charged up as part of the construction cost. In Victoria, however, the land for new State railways in country districts has to be acquired by a local Trust under Parliamentary powers, and handed over free of cost to the Government before construction work is started. The money to pay for this land is raised by a tax levied on all land which is enhanced in value by the building of the railway. This tax varies pro rata to the enhancement of the unimproved land value. In all cases, Crown lands are given for new railways without charge.

The costs of construction are limited to specific amounts by the Acts which authorise the lines. Should the limit be exceeded, special appeal has to be made to Parliament to authorise the increased expenditure.

Two principal methods are followed in carrying out railway construction, viz:

(1) Large Contracts.
(2) Direct Labor.

(1) Large Contracts.

The method of construction by letting large contracts was the general one from 1854, when railway construction in Australia commenced, till 1892. Since then, it has given place largely to construction by direct labor, i.e., by labor employed directly under Government supervision.

The large contracts have been for lengths up to about 100 miles (161 kilometres) and for amounts up to £2,000,000 ($9,600,000).

The contracts do not ordinarily include the supply of rails and fastenings. These are specially imported in large quantities and supplied to the contractors. Two steel plants equipped for rolling rails have now been started in the State of New South Wales at Lithgow and Newcastle, and promise to supply most, if not all, requirements when they get into full work. Buildings and other items of equipment, such as water supplies, are also the subjects of separate contracts.

The contracts have been in most cases based on a schedule of rates, the payments being made on the actual measurement of work done at the rate scheduled. Progress payments are made monthly at the rate of 90 per cent on the value of work done. Emergent work, for which no schedule rate was provided, has been paid at rates fixed by the Chief Engineer. It has also been the custom to provide heavy penalties for delay in completion of lines beyond the date specified in a contract.

A money deposit of 5 per cent on the total contract amount, as arrived at from the estimated total quantities of work and the contract rates, is required, and ten per cent of the value of work done to date is held back from progress payments as further security for the satisfactory completion of the contract, until the amount held is sufficient to give full security for satisfactory completion.

The conditions of contracts generally throw all risks on to the contractor, and give the Constructing Authorities very full powers for making alterations and additions to the work.

Specifications are usually couched in general terms, and only in the case of small contracts do they describe the work in detail.

The schedule to the contract shows the actual quantities of work required to be done as shown on the plans, sections and drawings, which form part of the contract. The number of items in the schedules is large, it being common practice to schedule all main line cuttings separately and also all stuff required to complete each separate embankment, and many contractors quote separate prices for each. In this way the number of items in the schedule often runs up to over one thousand. As a consequence of the large number of items in

the schedule, and the hurry with which contractors usually complete their tenders or bids, mistakes in arriving at the total amount are often made. It is the practice to keep a contractor to the amount shown at foot of his tender, and require alterations in prices to adjust errors in arithmetic.

Tenders may be submitted by anyone, without restriction, so long as the proper deposit of money is made along with them; and the practice is to accept the lowest tender, it being assumed that all contractors are of equal merit, unless they have been formally disqualified, which is very rarely done. It would often be more profitable to accept a tender from a contractor of good repute at higher cost rather than one from an unknown man or one who has given much trouble.

Contractors often adjust the prices in their contracts, thus speculating on the probability of the quantities shown in the schedule being exceeded or diminished, and also with the idea of getting in their profits chiefly from the items of work which have to be first carried out, and so practically having a set-off against their money deposit. The conditions of contract give power to the Chief Engineer to insist on adjustment of unreasonable prices or he may make a deduction from payments to protect the Constructing Authority.

The critical item of railway construction contracts is usually that for ballast, and the question whether the contractor shall make large profits or lose money on his contract often hangs on the opinion of the Chief Engineer as to whether ballast from a certain source complies with the specification.

In carrying out the contracts there is often much delay, as contractors think it pays them to wait over wet seasons or for a fall in market prices of materials, and take their chance of obtaining a remission of penalties for delay. In actual experience, the penalties have seldom been enforced, and the effect on contract work has been bad.

It has been the general practice to provide for a settlement of disputes which arise in settling up contracts by arbitration. The results of arbitration have been unsatisfactory. Contractors in many cases took up railway work at non-paying prices, either through ignorance of the value of the work or in the hope of making up losses by claims for extras and con-

cessions. In such cases, and in many others where the contractors had good prices, enormous claims for extras and allowances were made, and very heavy expenses were incurred in investigating or resisting and contesting such claims, and very large awards were in many cases made in favor of the contractors by irresponsible arbitrators.

In Victoria alone in a period of 10 years, seventeen contracts for 384 miles (618 kilometres) of railway, aggregating a cost of £1,320,904 ($6,340,339) under the Chief Engineer's final certificate, went to arbitration. Extra claims amounting to £416,594 ($1,999,651) were made by the contractors, on which the arbitrators awarded £111,993 ($537,566). The expenses incurred and paid by the Constructing Authority in addition came to £30,000 ($144,000). Other States had similar, and even more serious, experiences.

An appeal to the Supreme Court was also made by contractors on the ground that the powers given to the Chief Engineer by the conditions of contract were excessive and inequitable, but the Court held that when a contractor had signed the conditions with his eyes open he was bound by them. In recent years the Chief Engineer has, in some cases, been made sole arbitrator, and this practice has, on the whole, worked well. The Chief Engineer, in such cases, holds himself aloof from direct supervision of details of the contract.

(2) Direct Labor.

The difficulties and large expenses incurred in the settlement of contracts, the frequent long delays in completion of contracts, the desire to obtain more economical railway construction, and the wish to start works promptly in times of depression when large numbers of unemployed men are in want of work, led to the introduction of the Direct Labor system in Victoria in 1892, and since that date it has been used for all railway construction in Victoria, and largely followed in the other States of the Commonwealth, where, however, the practice has oscillated between the two systems—large contracts and direct labor—with a gradual increase in the proportion of direct labor work.

The work in Victoria has been under the direct supervision of the author, first, as Assistant to Francis Rennick, the

late Engineer in Chief, and for the past 12 years, as Chief Engineer for Railway Construction in the Department of Railways.

The following notes apply particularly to the working of the Direct Labor system of construction in the State of Victoria. The practice in other States has been similar in most respects.

All expenditure is charged directly to the money voted for the particular line. A strict, continuous audit is made by an outside auditor.

All the work has been completed to the satisfaction of the Railways Commissioners in whom the lines are vested for operation on their completion, except in one case where the estimated cost had been cut down by Parliament against the advice of the Chief Engineer.

This system has been tested on two occasions by calling for tenders or bids for 30-mile (48.28 kilometers) sections of construction. On the first occasion the lowest tender received was 10% higher than the Departmental estimate. It was rejected and the Department carried out the construction of the line by direct labor, and finished it at a cost below its own estimate. In the second case, a tender was received which was 1¾% lower than the Departmental estimate, but after investigation it was decided not to accept the tender, and the line was built by direct labor at a lower cost than if the contract had been accepted.

As a further check on the cost of the work, numerous tenders for items, such as earthworks and bridges, have been called for from time to time for works up to about £10,000 ($48,000) in value, and whenever bids were obtained which were not appreciably higher than the Departmental estimate these tenders have been accepted. A large proportion of these contracts turned out unsatisfactorily through the contractors failing to complete them, or being much behindhand in completing them, thus causing interference with other work.

The writer had freely expressed from time to time his opinion that when a change of conditions, bringing higher wage rates and a curtailed supply of efficient labor, arrived, the direct labor system would be more difficult to work, and

as these conditions arrived and the wage rate for laborers increased from 5/— ($1.20) per day of 8 hours to 9/— ($2.16) the advisability of a return to the "large contract" system was frequently considered, but it has been found that, while the cost of direct labor work has increased under these conditions, the cost of contract work has risen quite as much, and the former system has continued in full use up to the present.

The length of railroad built by direct labor in Victoria has been 1,239 miles (1994 kilometres), with an expenditure of £4,198,190 ($20,151,312). The number of lines constructed has been 56, and the cost per mile has varied between £1049 ($5035) and £85,560 ($410,688).

In carrying out work under the direct labor system, an Engineer is placed in control of the job, with suitable assistants, including a Pay Clerk, who acts as his accountant and is directly responsible to him, while he is responsible for the whole of the work, including all money payments made on the job. His duties thus cover a large scope, as he is Manager of the work as well as Engineer, and great care has to be exercised in selecting new men for the positions. Those who have made the best records have been trained in the service.

Drawings and specifications for the work are issued to the Engineers in charge from time to time as required.

The Department has often been called on to commence work under urgent conditions. The quickest record for starting work was made on an occasion when authority to proceed with construction was given, and a survey party and an engineer to take charge were sent to the work on the same day; one hundred men were sent to the work two days later and employed immediately. In this case, the first portion of the line was in easy country, so that the permanent location of a piece of the line could be marked, the section plotted and graded, and earthworks set out in 48 hours.

In employing workmen it is usual to put on suitable men who make application on the spot. Experienced railway workers find their way to new works in considerable numbers. When, however, the supply of these is not sufficient, requisitions are made on the Government Labor Bureau.

The men are provided with tents and cooking utensils, for

which they have to pay in instalments. Laborers have to pay for their own shovels and tradesmen have to provide their own small tools or pay for them; other tools are provided by the Department. The tents and tools supplied are not taken back from the men, except in cases where they leave before they have earned sufficient money to pay for them.

The climate of Victoria, and in fact of Australia, too, allows outdoor work to proceed all the year round; the greatest hindrances it makes being due to occasional heavy rains in winter near the coast and great heat and dryness inland in the summer.

Piecework is used as far as it can be applied to advantage. Simple work, such as barrow-led earthwork and bridge carpentry is done by gangs working at fixed rates, while work requiring the use of horses and plant is generally let in petty contracts made locally with men on the works. The pieceworkers and petty contractors sign a simple form of contract, which gives power to the Engineer-in-charge to stop the work at 24 hours' notice for any good reason.

When a local contract is taken up by one man, who employs other men, the form of contract provides further that his employes are to be paid directly by the Department at standard wage rates, and the amounts of such payments are deducted from the amount coming due to the contractor. Offers to carry out work at prices so low that there is no reasonable prospect of the contractor's earnings being sufficient to pay standard wages are rejected.

Fixed rates are arranged at the Head Office and are adjusted from time to time so that efficient, industrious men may make standard wages or a little more. Piecework men who fail to make earnings up to standard wage rates after a fair trial, and wage men who fail to work efficiently, are promptly dispensed with, the aim throughout being to pay prices which are fair both to the worker and the employer and to get a fair day's work for the day's pay. The Construction Acts require that the average earnings of the workmen as a body shall be not less than the standard wage. For the adjustment of piecework rates, test trials are made from time to time with gangs of men of average efficiency, working under capable

supervision on day wages. The actual earnings of pieceworkers are analysed and compared, both on individual jobs and between different lines, regularly.

There is an increasing tendency to do more of the work with gangs employed on day wages. These gangs, when under the control of capable gangers, working under effective supervision, and with a regular weeding-out of men who do not work efficiently, do good work, and, in many cases, do the work at rather less cost than pieceworkers.

All the work, whether done by the piece, by contract, or by day labor, is measured up fortnightly and the costs compared with other work, so that inefficient gangs may be promptly dealt with.

The hours of work in Victoria are 48 hours per week, which has to be worked at the rate of 8 hours on each week day in two shifts of 4 hours each. The starting and stopping times are the same throughout the job, except when specially authorised otherwise by the Head Office. Overtime and Sunday work are discouraged.

A thorough system of time-keeping is kept in operation, and includes the apportionment of the time to the different items of work in a rather elaborate schedule of apportionments, including sufficient information for an analysis of costs. As an example, the items in connection with a cutting are as follows:

Ganger
Ploughing
Explosives
Getting, filling and trimming
Leading by .... (average lead .... chains)
Tipping and trimming bank
Carting fodder and water

The workmen are paid fortnightly, but necessitous men who are taken on receive advances during their first fortnight's employment, up to an amount of 10/—($2.40) per week, as they earn it, in order that they may buy food. After the first fortnight, no further advances are made. This is done in order to put the workmen in the position of being able to

pay cash for all the purchases that they may have to make from the purveyors of rations, who usually visit the works two or three times a week and compete with one another for the men's custom. All storekeepers and others selling goods to employes are advised not to sell on credit, though they frequently do so to their sorrow. In remote localities the men are supplied with rations by the Constructing Authority and charged cost price.

Steel girders, bolts and spikes, sawn timber, fencing wire, explosives, bricks, cement, and other materials are obtained by public contracts for the separate items. Sleepers, timber fence posts, piles, telegraph poles, and parts of the bridge timber are obtained by petty contracts let to small parties of timber hewers, who deliver at the nearest point of a railway to the forest and are paid in cash on delivery.

The standard rates of wage at present current are as follow:

	s. d.		
Concrete Laborers	9/6	($2.28)	per day.
Laborers	9/–	($2.16)	" "
Leading Hands	10/–	($2.40)	" "
Batter Men, Tip Men, Jumper Men — First class men only	9/6	($2.28)	" "
Platelayers	9/6	($2.28)	" "
Ploughmen—Picked men	9/6	($2.28)	" "
Blacksmiths	11/–	($2.84)	" "
Bricklayers	11/–	($2.84)	" "
Carpenters—Bridge work	11/–	($2.84)	" "
Masons	1/4½	($0.33)	" hour.
Painters	11/–	($2.84)	" day.
Gangers—Ordinary (or as specially approved)	10/–	($2.40)	" "
Horse, Tip Dray and Adult Driver [Driver 9/– ($2.16), horse and dray 5/6 ($1.32); each extra horse 5/– ($1.20).]	14/6	($3.48)	" "

The staff in charge of a construction job is provided with quarters in temporary buildings and tents, and the Department provides the cook and mess equipment. In return for these concessions, the members of the staff are required to be available at any hours which the Engineer in charge may desire,

but any officer who is kept on duty over an extended period for long hours can apply for and be allowed time off in consideration. The organization of the staff is shown in the Appendix.

Very large piecework gangs have been worked from time to time on heavy excavation work by fixing a piecework rate and placing a competent foreman over the men to direct their operations and to see that they work efficiently and pull together. The extra output obtained in this way often more than pays the foreman's wages.

The Direct Labor system has shown the following advantages:

(1) A saving in time.

The period required under the old contract system for completing surveys, plans, quantities, specifications, and drawings, advertising and letting contracts, which extended over many months, has all been saved, and the expense so incurred largely reduced; also, the actual work of construction has been carried out, on the average, in about two-thirds of the time taken by contractors. Work is often started on the heels of the surveyors who locate the line.

(2) A saving in cost.

Instead of a contractor paying a staff to carry on the work, while the Department paid another staff of officers and inspectors to supervise them, one staff under the Department now does all the work, while the workmen do the work as well and as cheaply for the Government as for a contractor, when properly handled.

The contractor's financial and commercial arrangements were often badly made and caused loss to him, and loss and trouble to the Constructing Authority. The percentage included in the contractor's prices to give him a profit is saved. Money with which to carry on the work is obtained by the Government at half the rates of interest which contractors often pay.

The heavy claims which were made in connection with large contracts and only settled with great expense and trouble, often by tedious and costly arbitration, are quite avoided.

Partial stoppages of work, shifting of station sites, and alterations of design, which usually led up to the large claims,

are now made more freely and, in most cases, have only small effect on the cost of the works; while other unforeseen contingencies are dealt with promptly and easily. Full advantage is taken of cheaper materials discovered when carrying out works, and of fluctuations in market rates. Modifications in design and execution are freely introduced when economy or efficiency may result. Contractors, when tendering, had to make large allowance for providing plant, including locomotives and trucks, which might be left idle on their hands, with poor opportunities of realising at reasonable prices, and, in many cases, made shift with very inferior wasteful plant in consequence. Under the Direct Labor system, all construction in the State being done by one party, better plant is provided and it is more regularly utilised, the cost for any individual line being thus largely decreased.

(3) Other advantages which apply to Government work are:

That it has been possible to distribute employment systematically and fairly among the unemployed workers of the State, and also to secure payment of standard rates of wages without the difficulties which have occurred in enforcing the minimum wage clause under contracts.

Generally speaking, the men have worked contentedly. Complaints from them have been fewer than might have been expected and have been fairly met and dealt with. In twenty-three years there has not been one large strike, and occasional small ones have been handled easily till they fizzled out.

In comparison with contract work, the Departmental Officers may not have the stimulus of increased profit to urge them on to strict economy and keep them keen in reduction of costs, but with diligent, effective supervision and control by competent officers, the efficiency of working is little, if any, behind the average of contract work.

EQUIPMENT.

The equipment of plant and tools for railway construction work in Australia has been supplied chiefly by importation from older countries, and there is not much that is new or original to describe.

Locomotives of American type being more suitable for running on unfinished tracks and roughly laid temporary sidings than the stiffer engines of English and European design give the best satisfaction.

For work trains, a truck designed in Victoria with body 33 feet (10 metres) long, built with low hinged sides, sunken hopper and trap doors for ballasting is giving much satisfaction. It is easily adaptable for carrying rails of standard lengths. Ballast trucks of the "Rodger" pattern are also used. Many old-fashioned four-wheeled trucks are still in use and are very handy for jobbing work.

Ballast ploughs are used to a small extent.

Steam shovels of both American and English makes are in use in comparatively small numbers. Much of the construction requires only light earthworks, which do not give scope for them. Heavy cost of transport beyond the rail head, difficulty in working them in single line cuttings, and in training men to handle them effectively have also checked their use.

Ballast loaders of different types have been used, but, owing to their limited reach for picking up the ballast, have not become general.

In a country where work can usually proceed all the year round, and the conditions seldom require the laying of so much as one mile of track per day, there is not much scope for track-laying machines. Two machines of the Roberts pattern are in use on a transcontinental line of 1,063 miles (1,711 kilometres) in length.

In districts similar to the American prairies, grading machines, wheel scoops, drag scoops, and buck scrapers, usually of American manufacture, are used. The long, heavy English ploughs are giving place to American ploughs with short steel beam and mould board.

The two-wheeled tip dray, holding about nine tenths of a cubic yard and drawn by one horse with a driver to each dray, is holding out against the four-wheeled dump wagons of larger capacity drawn by two horses, on account of its handiness. The dump wagons have been introduced and used to a small extent in work which best suits them. Wages have increased lately and it is expected that this will lead to their more general use.

Long leading of stuff is often done with muck wagons of the fiddlestick pattern running on temporary track and drawn by horses. They hold from 2½ to 3½ cubic yards (2 to 3 cubic metres) and are tipped at speed by running against a bumping log, the pedestals lifting right off the hind axles. Small steel wagons of two-feet gauge running on light rails, with trays holding three quarters of a yard and tipping on either side, are much used. They can be easily altered to tip at the end of the track. They are drawn in rakes by horses and give better results than tip drays on much of the work, especially on the longer leads.

In small tools there is little of special interest to note. The old English No. 4 navvy shovel is practically standard. A shovel with a straight handle about five feet (1½ metres) long is used for throwing earth up high lifts, but its superiority over the short handled shovel is doubtful.

Bridge foundation and erection plants are of patterns evolved in other parts of the world.

Pile driving is usually done by an iron monkey weighing about thirty hundredweight (1527 kilogrammes) hoisted by a steam winch and tripped by hand to fall about ten feet (3 metres). Steam pilehammers are little used, if at all.

Stone crushers of both the parallel jaw and gyratory type are used, and the latter are increasing in favor.

In track work, track jacks with ratchet and pawls made locally are found useful. Packing of rock ballast is done with a beater, which is like a double-ended pick with one end T-shaped, with a flat face about 2½ inches by ⅞ inch (.064 by .0023 metres).

This is preferred to a tamping bar, as the wide spacing of the hardwood sleepers, 2′ 9″ to 3′ 0″ (.838 to .914 metres) centres, and their depth of only five inches (.127 metres) give room for the beater to drive the ballast well in under the sleeper.

Sleeper adzing and boring are done with machines designed locally to suit the hard timber in use. The sleepers pass over revolving cutters, which cut the rail seat to a cant of 1 in 20 and are then turned over and the spike holes bored with augers which descend from above.

Note.—On the date of mailing the above, it is just announced that the New South Wales Government has made a contract with an English firm to carry out railway construction works to the value of £10,000,000 ($48,000,000).

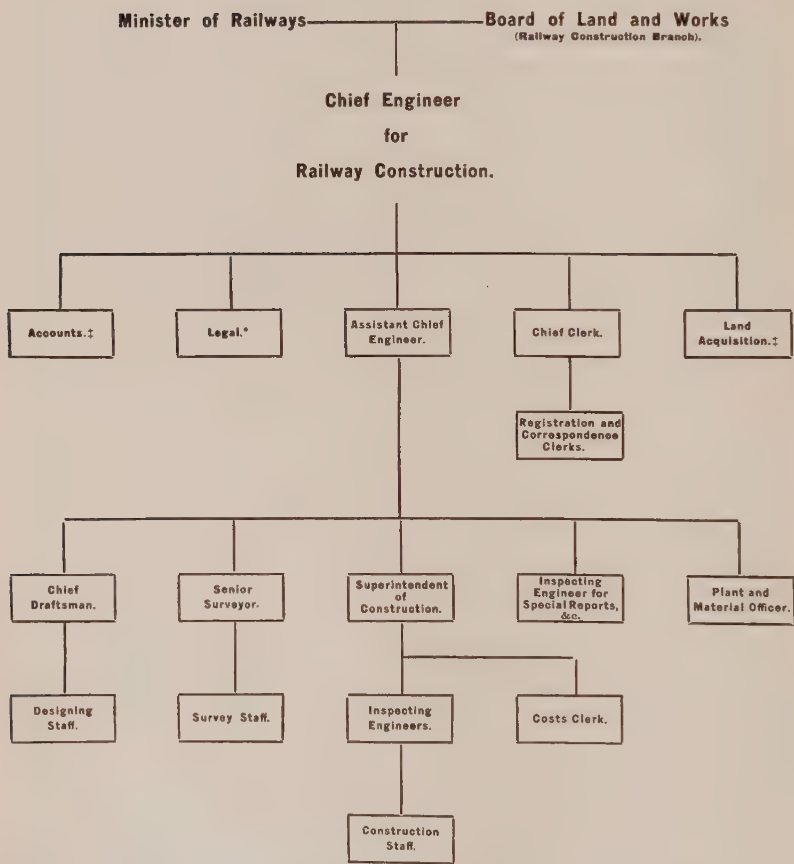
The exact conditions are not yet made public, but negotiations in another State with the same firm were on the proposed basis of an estimate to be agreed upon by both contracting parties, the work to be carried out to the satisfaction of the Government Engineer, the Contractor's books to be the subject of audit by a Government Auditor, and payments to be made on his certificate. If the work cost more than the estimate, the payments by the Government were not to exceed the estimate; and if the work cost less than the estimate, the Contractor was to be paid the actual cost, plus half the savings. The Contractor was to receive, in addition, a remuneration of 7½% on the estimate, and to accept payment in Government debentures at a price valued at a rate per £100 to be agreed upon, and to enter into a bond to keep the debentures off the public money market for a fixed number of years.

APPENDIX.

ORGANIZATION OF RAILWAY CONSTRUCTION BRANCH

OF

VICTORIAN RAILWAY DEPARTMENT.



‡ The Services of the Chief Accountant to the Railways Commissioners, and of the Estate Officer to the Railways Commissioners are "in part made use of" under the provisions of Act No. 1250 for Accounts and Land Acquisition.

* Conveyancing and law work are carried out by the Crown Solicitor

Paper No. 83

TUNNELS.

By

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INTRODUCTION.

The construction of tunnels in America in recent years has been much more rapid than is indicated by the increase in the mileage of the railroads themselves. Their need has arisen from three causes:

1 From the construction of new railroad lines

2 From the improvement of alignment and grades; also in connection with the double-tracking of existing lines, and enlargement of sections that are considered small

3 From the construction of important terminals

While those of the first and third classes are generally described in the various engineering publications, many of those included in the second class, which are the greatest in number, do not appear. For example, on a railroad having a present length of a little over two thousand miles, there were added since 1904 for the construction of branch lines twelve tunnels having an aggregate length of 7863 feet, the maximum length of any single tunnel being 4770 feet; while those added in connection with double-track and improving lines and on low grade lines numbered thirty-two, having an aggregate length of 32,251 feet, the maximum length of any single tunnel being 3291 feet.

Some examples of tunnels constructed for these reasons, and coming under the second class, are:

The Snoqualmie tunnel through the Cascade mountains

(Chicago, Milwaukee & St. Paul Ry.), 11,890 feet long. Completed January, 1915.

The Rogers Pass tunnel on the Canadian Pacific Railroad, which will be a double-tracked tunnel five miles in length, the work on which was begun in 1913.

The Nicholson tunnel, on the Delaware, Lackawanna & Western Railroad, a double-tracked tunnel 3630 feet long, to be completed early in 1915.

Examples of the third class are the Seattle tunnel, which is a double-tracked tunnel for terminal purposes at Seattle; length, 5141 feet; completed in 1905.

The Mount Royal tunnel, on the Canadian Northern Railroad, Montreal, Canada, which is a double-tracked tunnel having a length of 17,000 feet, built for the purpose of entering the terminal station at Montreal. Completed in 1914.

The tunnels under Bergen Hill, North River, City of New York, and East River, which provide entrance into New York for the Pennsylvania Railroad System, and which have been in operation for some time, are built for two or more tracks for a length of 27,052 feet.

The American Railway Engineering Association in its Manual of 1911 publishes therein, as representing good practice for new construction, single-track tunnels 16 feet wide, with a clear height from base of rail of 22½ feet; double-track tunnels to furnish the same clear width outside of each track and the same height over the center of each track. The tunnels constructed during recent years approach these dimensions where steam locomotives are used exclusively, but where electric power is used, much smaller cross-sectional area is followed in good practice. The Mount Royal tunnel referred to, at Montreal, and the Pennsylvania tunnels in New York present examples of these.

With the rapid increase in the use of electric power, it is probable that not only will it become unnecessary to widen many existing tunnels, but tunnels that are built in the future will be of this smaller cross-sectional area; such, for example, as the single-track section of the Pennsylvania tunnels in New York, which has 225 square feet of area above the track. It may be said, therefore, that so far as dimensions of cross-sec-

tions are concerned the art of tunnel design is in a state of transition, in that those dimensions depend upon the probable style of power that will hereafter be used.

The methods of constructing tunnels, involving elements that make up the cost thereof, have also been in somewhat of a transitional state during recent years on account of the effort of every party interested therein to secure their construction at a comparatively high rate of speed and still at as low a total cost as practicable. The brief outline which follows, of the methods used in constructing a number of recently built tunnels, has been compiled in order to call attention to, and bring out discussion of, the different typical methods of construction that have been followed in recent years, under the usual varying conditions met with in tunnel work—methods that have been used, primarily, for the purpose of securing speed, combined with safety, economy in construction, and the best means for securing proper ventilation.

In this outline, the areas of cross-sections are given, and the number of cubic yards of material removed per foot of advance of both heading and entire tunnel section are recorded, together with the rates of progress, in order that a correct comparison may be made of all the results secured under each method of procedure.

SNOQUALMIE TUNNEL.

On Change of Line at Snoqualmie Pass, Cascade Mountains, Sixty Miles East of Seattle, Washington; Chicago, Milwaukee & St. Paul Ry.

Single-track tunnel, 11,890 feet long, opened for traffic in January, 1915. Length of new line, including tunnel, 4.5 miles. The object of building this tunnel is to shorten length of line 3.7 miles; reduce Summit Hill, and eliminate 443.5 ft. of rise and fall (made up of westbound 4.7 miles of 2.2% grade, eastbound 4.4 miles of 2.75% grade); to cut curvature 1239°; to decrease snow trouble resulting from a fall exceeding fifty feet in some seasons; to reduce pusher service to a minimum and save in operating cost.

For the greater portion of the distance the bore passes through bodies of massive black slate, intercepted by compara-

tively thin strata of grey quartzite, blue conglomerate and an andesite dike; all of which dip to the east with an angle of approximately 75 degrees to the horizontal. The formations are generally shown on Plate I, which also shows the location with plan and profile of tunnel.

Plate II shows method of excavation and plan of doing the work.

Plate III shows the completed cross-section of tunnel.

The width of the completed tunnel section is 16 feet; area to subgrade, 352 sq. ft.; area above track, 337 sq. ft.; crown of arch to base of rail, 22 ft. 5 in. (see Plate III). Average section excavated, about 517 square feet, making about 19.2 cu. yds. per foot of tunnel. Owing to the nature of the ground—there being much debris, fractured rock and water—the 436 ft. of the west end of the tunnel were driven by the top heading method, and enlarged and timbered to a standard section to allow concrete lining without removal of the timber. The remainder of the work from the west end was done by the bottom heading method, which was considered most economical, as providing means for trapping material from above directly into cars in the completed heading, and because progress in removal of the balance of the section was not dependent upon the use of shovel.

A heading 8x13 feet, requiring removal of about four cubic yards per foot advance, was driven at subgrade and along the north line of the tunnel section and was kept from 1000 to 2000 feet in advance of the bench, the distance varying with the progress of the bench, which was dependent upon the labor situation. The order of procedure is shown on Plate II.

Work in the heading was carried on continuously, the crew consisting of three shifts of four machine runners, four helpers, ten muckers, two nippers and two shift bosses. The runners, helpers and muckers worked six-hour shifts, laying off twelve; the nippers and shift bosses worked twelve hours.

Fourteen to thirty 9-ft. holes were drilled for each shot, depending on rock encountered, the drills being mounted on a cross-bar four feet above subgrade, four holes being drilled below the bar, acting as lifters, and all others above the bar.

Average break per shot was about 6.1 ft.; average time

between shots, 15.5 hours; and average daily progress, 9.5 ft.; maximum progress in any one day having been 25 ft.

These figures are averages for the entire distance of west heading; however, under favorable conditions a shot was fired about every twelve hours, the time being divided about as follows:

Two and one-half to three hours breaking down roof and mucking back; seven hours setting up cross-bar, drilling and mucking out; one hour taking down, clearing and shooting; and one hour waiting for the heading to clear of the gases. Many exceptions to the above were encountered, an example being the andesite dike where twenty-four hours were taken to drill one round.

Before a shot was fired, steel shoveling sheets were laid on the floor and up against the face of the heading so that the muck, which was broken finely, could easily be shoveled to the low heading cars of one yard capacity.

All heading work was considered "preferred" and carried a bonus to all directly connected; a bonus of one hour's time being given for each foot over ten feet per day, bonus paid every ten days.

Following the advance heading a crew winged it to full tunnel section width, after which the trap or stoping timbers were placed. Bench openings were then driven to full tunnel section at intervals of a hundred and fifty feet, from which the bench was worked both ways. As a usual thing, the entire face was drilled and shot at one time, in that way giving the machine runners and muckers continuous work in each stope.

Average progress on the west-end bench was 7.7 feet per day; however, this cannot be taken as a criterion as to what speed could be obtained, as the bench work was held up for some time due to the fact that the work was carried on with a limited payroll, and when labor was scarce the heading was pushed at the expense of the bench progress.

Several timbering schemes were used; the first 436 feet at the west end was standard tunnel timbering, to be concreted in place; the remainder of the work had stoping timbers, to take out the bench, and where the roof was at all treacherous, an "A" frame was built up from the stope bent and the roof

held by crown bars, all to be removed ahead of the concreting; where the roof was good, the stoping timbers were taken down and moved ahead. "A" timbers were used from Station 10 to Station 26; remainder of tunnel, except in a few places, was not timbered, as the lining work followed the bench closely.

Work at the east end of the tunnel was not started until in 1913, and due to the fact that the approach cut was not completed the tunnel was driven by the center top-heading method. The amount excavated per foot advance in heading averaged about 2½ yards. The heading was winged to the wall plates; shafts were sunk to subgrade at several places and bottom drifts run both ways so that when the approach cut was complete the bench material could be stoped out, as on the west end, the material being used to make the fill for the railroad yard at the east end of the tunnel.

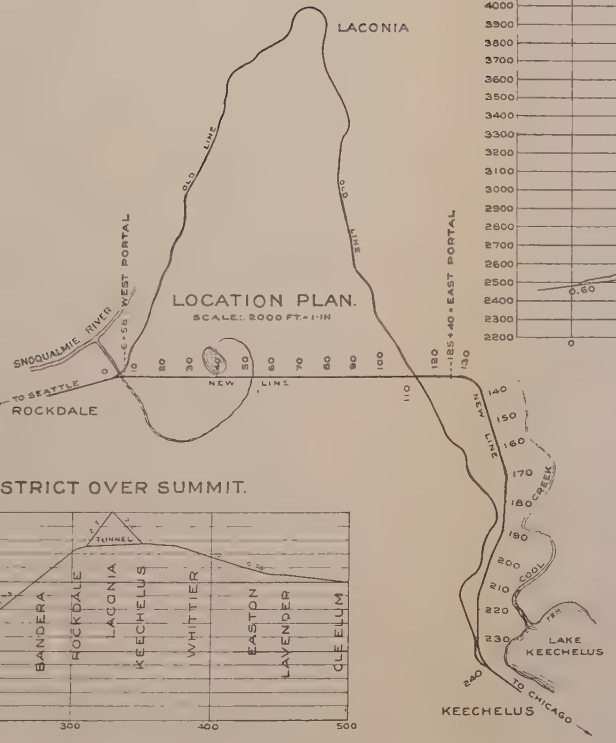
Driving data, west end, are as follows: prior to April 26, 1912—436 feet top heading. June 1, 1912, to August 4, 1914—6971 lineal feet of bottom heading. Average per day, 9.5 feet. Maximum progress per day, 25 feet; 77 days shut down to wing out. Average progress per shot, 6.1 feet. Average time between shots, 15.5 hours. Maximum monthly progress (March, 1913), 455 lineal feet.

Driving data, east end: May 1, 1913, to August 4, 1914—4483 lineal feet of heading. Average per day, 10 lineal feet. Average progress per shot, 5.4 feet. Average time between shots, 13.1 hours. Maximum monthly progress (September, 1914), 433 lineal feet.

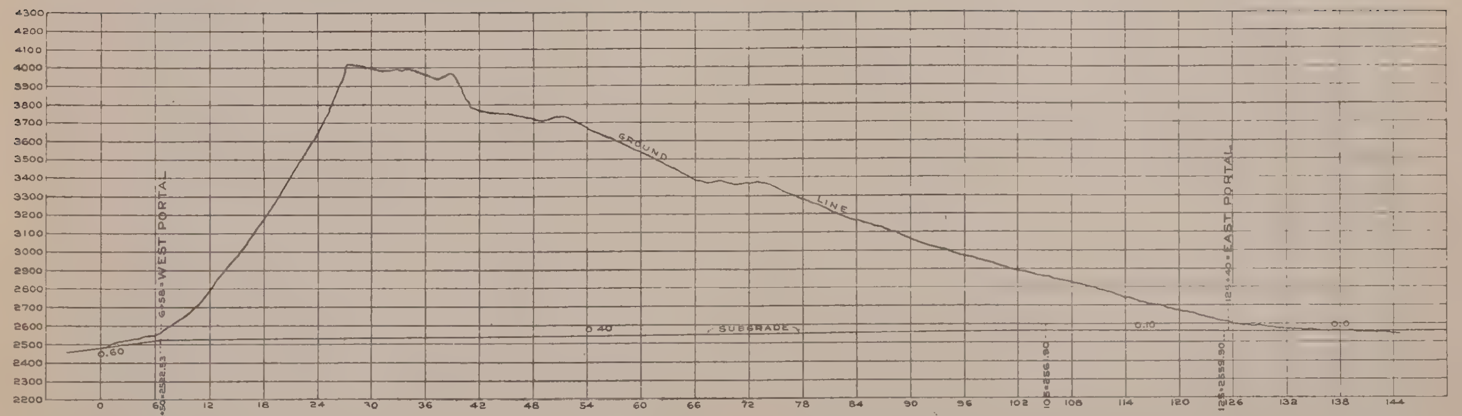
Bench progress for the west end is as follows: average progress, 7.7 feet. Maximum monthly progress (November, 1914), 658 lineal feet. For the east end: average progress, 10.3 feet. Maximum monthly progress (November, 1914), 644 lineal feet.

Dynamite used per foot advance of tunnel, 55¼ lbs., costing $8.27. Quantity of dynamite used per cu. yd. of tunnel excavation, 2.8 lbs.

While the rock encountered was hard and unaffected by weather, it was so stratified, fractured and filled with soft talc seams that lining throughout was a necessity. The lining section is shown on Plate III, a comparatively simple section



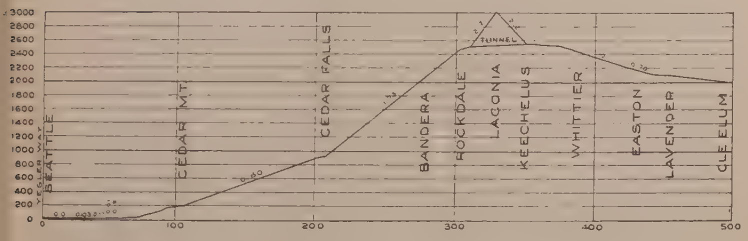
LOCATION PLAN.
SCALE: 2000 FT. = 1 IN.

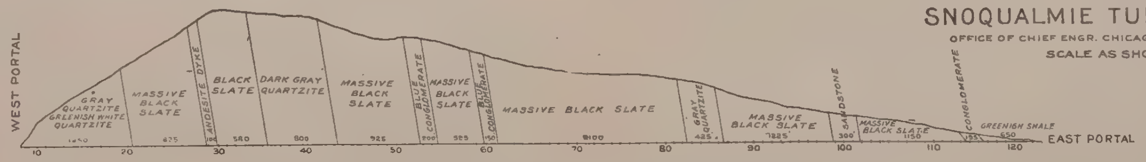


PROFILE OF TUNNEL

C.M & ST. P. RY.
PLAN & PROFILE
SNOQUALMIE TUNNEL, WASH.
OFFICE OF CHIEF ENGR. CHICAGO, ILL. NOV. 21-1914
SCALE AS SHOWN

PROFILE OF ENGINE DISTRICT OVER SUMMIT.





CROSS-SECTION OF ROCK FORMATIONS
INFORMATION OBTAINED FROM GEOLOGICAL REPORT AND
SHOWS FORMATION EXPECTED IN DRIVING TUNNEL

Plate I.

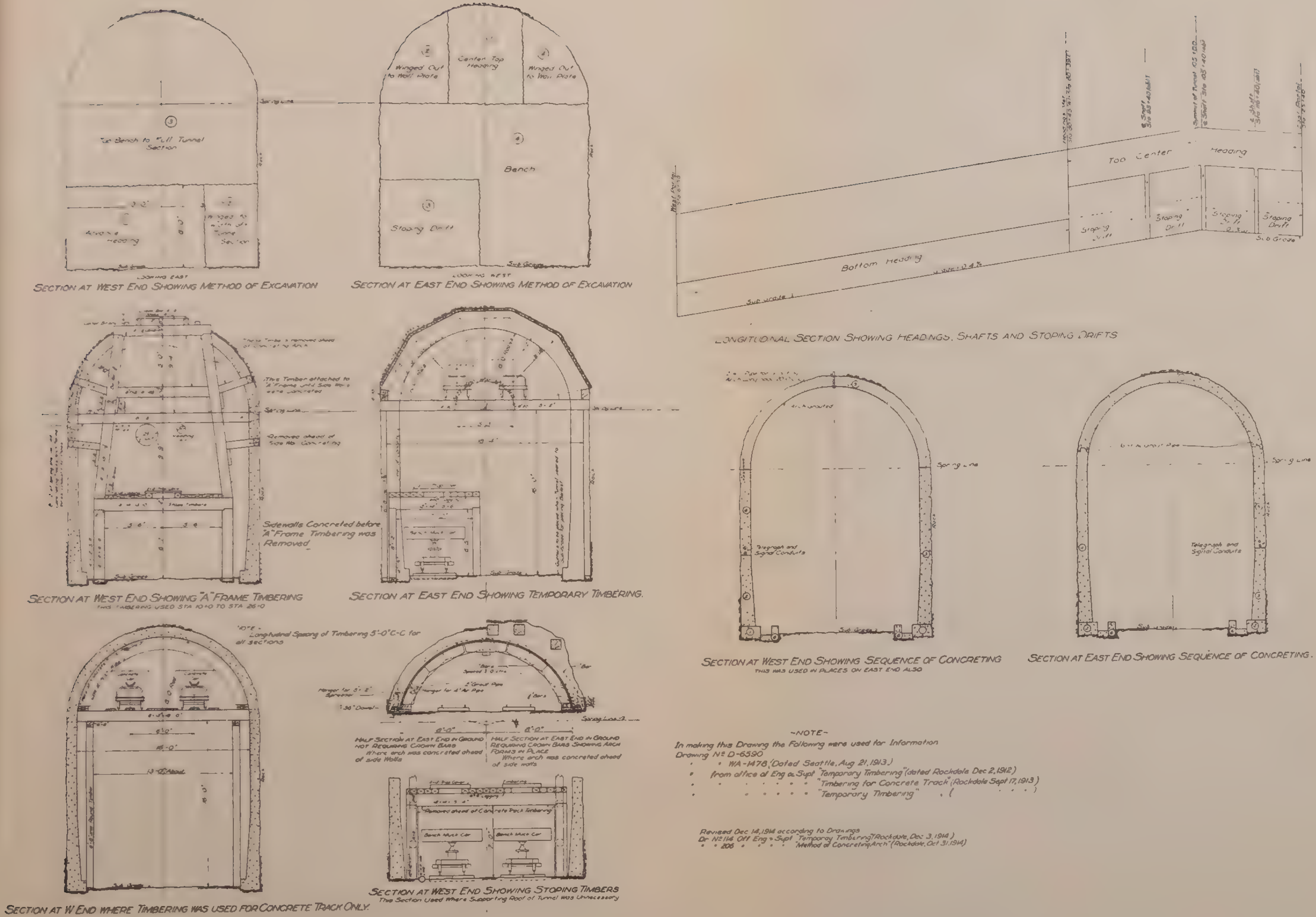


Plate II. C. M. & St. P. Ry., Snoqualmie Tunnel. Timbering Schemes and Stages in Excavation and Construction.

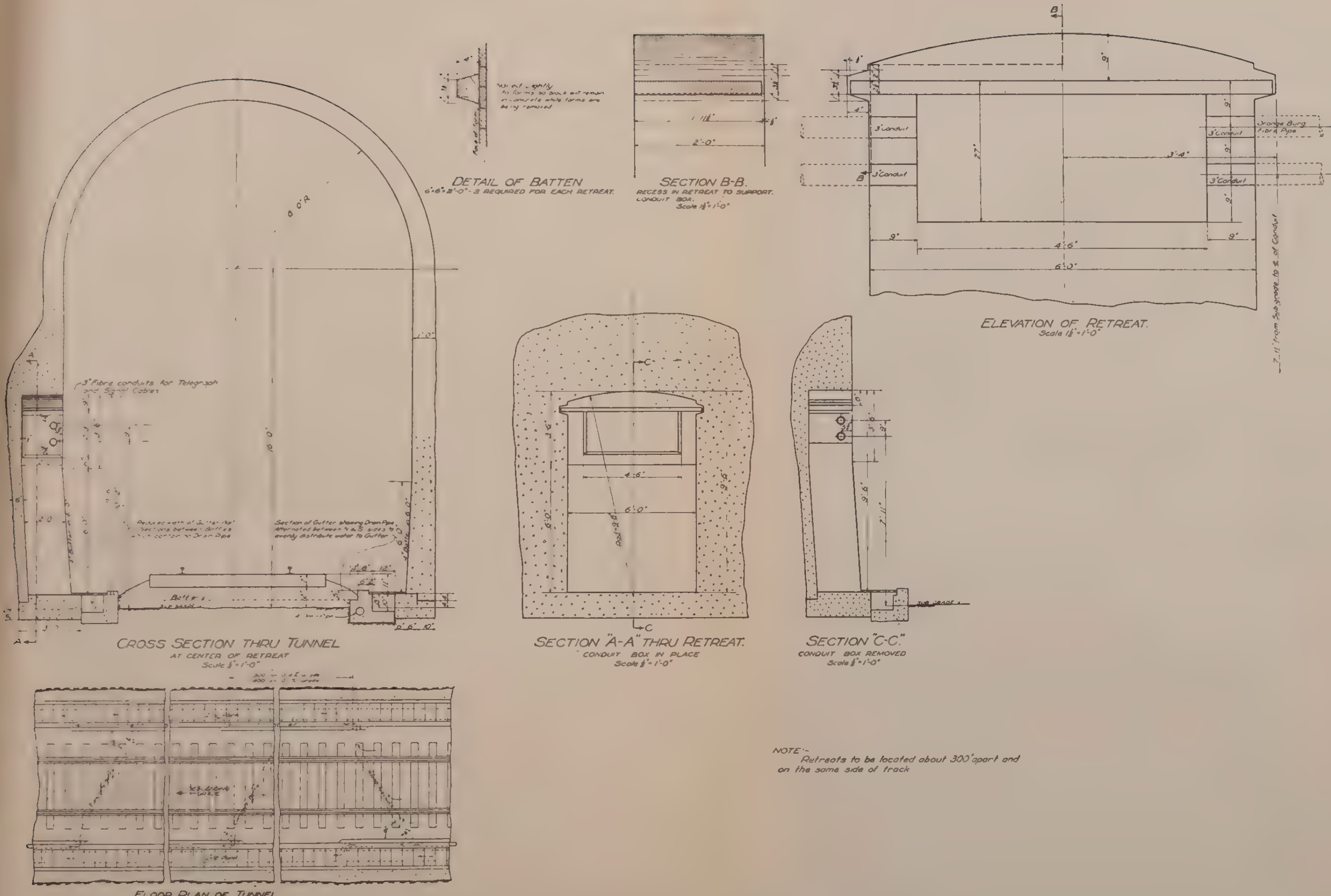


Plate III. C. M. & St. P. Ry., Snoqualmie Tunnel. Cross Section and Retreat Details.

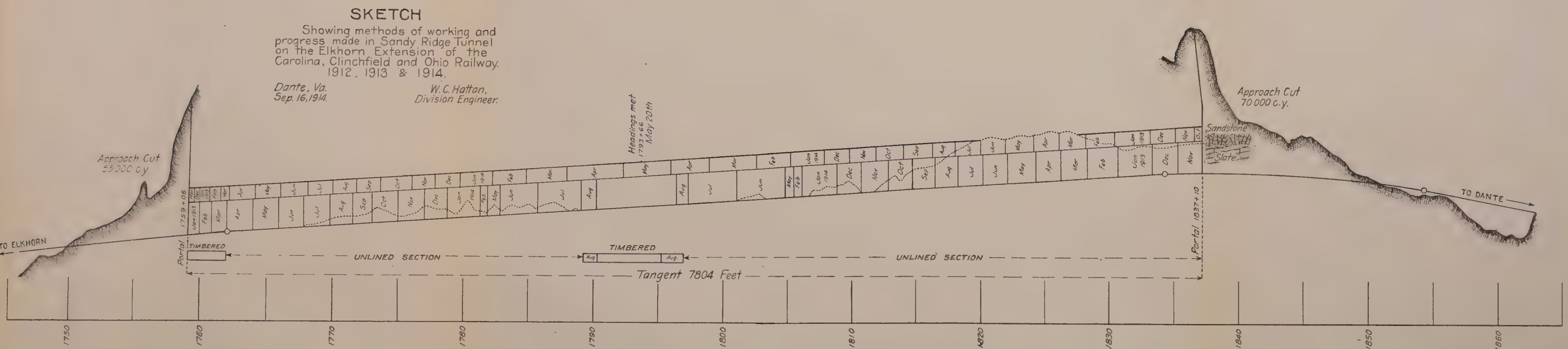

SKETCH
Showing methods of working and progress made in Sandy Ridge Tunnel on the Elkhorn Extension of the Carolina, Clinchfield and Ohio Railway. 1912, 1913 & 1914.
Dante, Va.
Sep. 16, 1914.
W. C. Hatton,
Division Engineer.
Headings met
1793+66
May 20th
Approach Cut
55 000 c.y.
Approach Cut
70 000 c.y.
Sandstone
Slate
TO ELKHORN
TO DANTE
Portal
1759+06
Portal 1837+10
TIMBERED
TIMBERED
UNLINED SECTION
UNLINED SECTION
Tangent 7804 Feet
1750
1760
1770
1780
1790
1800
1810
1820
1830
1840
1850
1860

Plate IV.

to build, and concrete was easily placed from the high-line timbers. Concrete lining in the tunnel averages about 6.1 cubic yards per lineal foot.

The main concrete plant, capable of handling 150 cu. yds. of concrete in a day of ten hours, was built outside the tunnel at the west end, and the work of concreting from the west end progressed while tunnel excavation was in progress. Concrete work at the east end was started as soon as sufficient full section was excavated at that end. The east heading struck some bad ground, and to save timbering, the arch was concreted from the east concrete plant before the bench was removed, and in so doing a great saving was made in cost of timbering.

Ventilation at both ends of the work was accomplished by exhaust method, a large fan in the power house being connected to a 2-ft. ventilation pipe that opened at the end of the enlarged section. In addition to this, an auxiliary plant at each end forced air into the heading through a 10-inch pipe, a canvas section being used within 100 feet of the face to allow its quick removal at time of firing a shot.

SANDY RIDGE TUNNEL.

On Elkhorn Extension of Carolina, Clinchfield & Ohio Ry., at Dante, Virginia.

Single-track tunnel, which was completed in 1914; length, 7804 feet. The permanent lining of the tunnel is in progress.

Plate IV contains a profile of the tunnel showing the line of cleavage between sandstone and slate, the two materials mostly encountered. It also shows the monthly progress from the time the excavation was started, in October, 1912. Sketches on Plate V indicate the method of excavation adopted, the top center heading system having been used, working from each end of the tunnel.

The minimum width of the lined tunnel section will be eighteen feet; maximum, nineteen feet. The minimum square feet of area is 364; maximum, 378.

The average area of the excavation made, including falls, was 625 square feet, requiring the removal of 23 cubic yards per lineal foot of tunnel.

The average area of heading removed was 85 square feet,

or 3.1 cu. yds. per lineal foot of tunnel, but where timber lining was required the excavation of heading material was increased to 6.5 cu. yds. per lineal foot of tunnel.

The area of the sub-bench removed averaged 132 square feet. The work was planned to keep the sub-bench about 8 feet behind the heading; and the drilling to progress in such a manner that the holes in heading, in the sub-bench, and the full bench could be fired in a series of shots that would result in an advance of the full tunnel section of from 7 to 8 feet.

Figure 1, on Plate V, illustrates the methods of drilling and shooting. Ordinarily, 22 to 24 holes were placed in the heading, using the V-cut method. Twelve-foot drills were run in the cut holes, starting about eight feet apart at the face of the heading and bottoming from 12 to 18 inches apart. Ten-foot drills were run in the side rounds. From seven to eight feet were removed as a result of one blast. Two rows of vertical holes, twelve in all, were drilled in the sub-bench, the length of drills being eight feet. Four holes were drilled in the full bench, with two side holes at times. The two center holes were sprung three times, and the side holes twice, to form a powder chamber. All other holes were shot straight. This method of springing full-bench holes is responsible for some additional breakage in the side walls, but was adopted in order to secure the greatest possible rate of progress. Up to September, 1913, the benches were carried immediately behind each heading, and a weekly progress of 45 feet was made in each end of the tunnel. In September, 1913, the bench was kept 80 feet behind the headings. This method was followed until February, 1914, making a weekly progress of 50 feet at each end of the tunnel. At this date it was decided, on account of ventilation, to stop work on benches temporarily and drive the headings alone. This course was followed, the headings meeting on May 20, 1914. Work was resumed on the benches in May, 1914, and excavation was completed in November, 1914, notwithstanding more temporary timbering was required than anticipated.

The work in this tunnel was in progress almost continuously, the men being under pay about 22 hours per day for six days in the week. The labor worked in two shifts of ten hours per day.

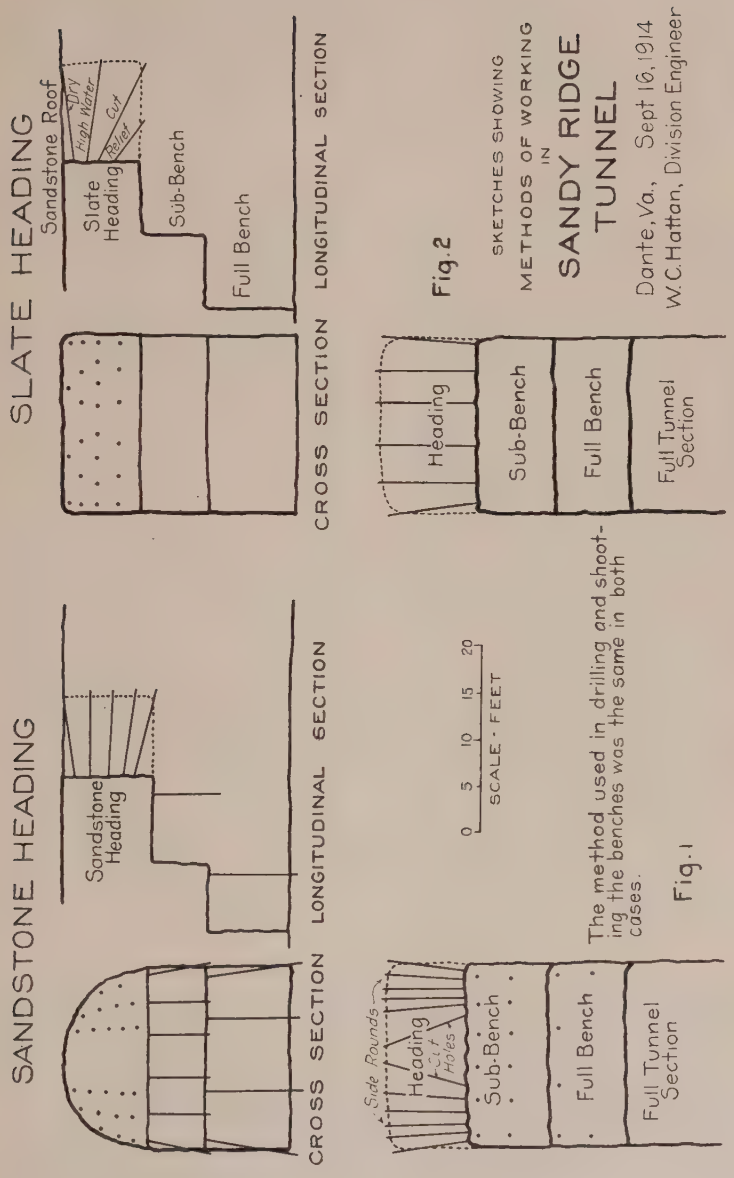

SANDSTONE HEADING
CROSS SECTION
Sandstone Heading
LONGITUDINAL SECTION
0 5 10 15 20
SCALE - FEET
Side Rounds
Heading
Cut Holes
Sub-Bench
Full Bench
Full Tunnel Section
PLAN
The method used in drilling and shooting the benches was the same in both cases.
Fig. 1
SLATE HEADING
CROSS SECTION
Sandstone Roof
Dry
High Water
Cut
Relief
Slate Heading
Sub-Bench
Full Bench
LONGITUDINAL SECTION
Heading
Sub-Bench
Full Bench
Full Tunnel Section
PLAN
Fig. 2
SKETCHES SHOWING
METHODS OF WORKING
IN
SANDY RIDGE
TUNNEL
Dante, Va., Sept 16, 1914
W.C. Hattan, Division Engineer

Plate V.

In the excavation the contractors averaged about 700 lbs. of 60% N. G. dynamite for each round, or shot, to secure an advance in the full tunnel section of from 7 to 8 feet. The best progress made in one week was in January, 1914, when a total of 130 feet of heading was removed in six days, and 147 feet of bench.

When heading alone was driven, the best progress made in any one week of six days was in March, 1914, when 169 feet of headway was made. The best progress made in bench, after heading had been completed, was during one week in July, when 177 feet of bench was excavated in six days.

The material removed during excavation was largely used in making fills, the longest haul from the north end being 5600 feet, and 2800 feet from the south end of the tunnel.

Electric current taken from a coal operation furnished power to air-compressor plant, compressed air having been used for operating all drills, shovels, etc.

The first 2000 feet of tunnel from the portal was taken out without ventilation, other than the exhaust from the drills and shovel. After these points were reached a pressure exhauster was installed near each portal, with a capacity of 3500 cubic feet per minute. These fans drew the smoke and gases from the tunnel through a fourteen-inch galvanized ventilating pipe, which was carried along the bottom of the tunnel to a point near the rear of the shovel. This method was followed until the heading was completed, after which the natural ventilation was satisfactory.

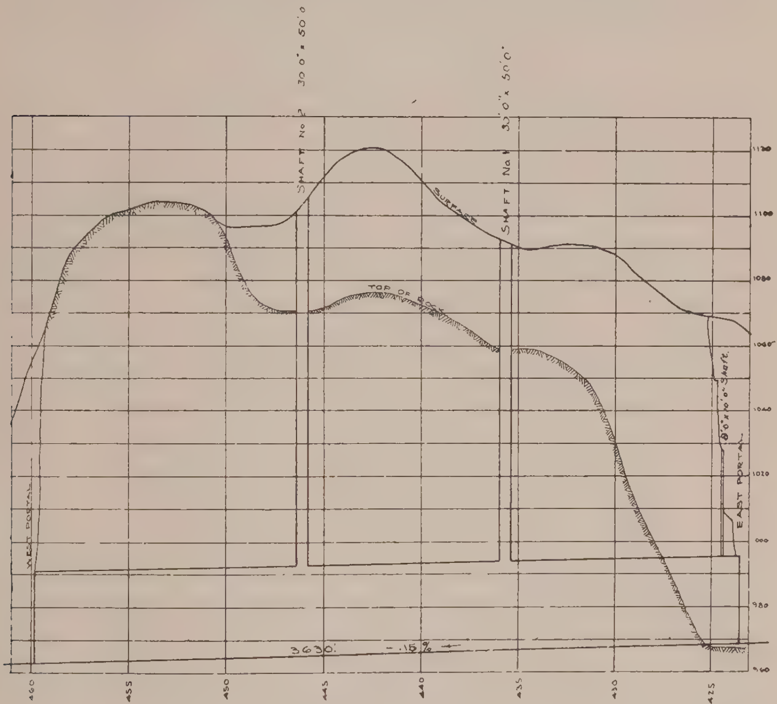
A permanent ventilating plant will be installed at the upper, or south, portal, driving fresh air through the tunnel to the north end.

NICHOLSON TUNNEL.

On Change of Line, Clark's Summit to Hallstead; Delaware, Lackawanna & Western Railroad.

Double-track tunnel, lining to be completed early in 1915. Length, 3630 feet. Figure 1 shows a longitudinal section of tunnel, with location and dimension of the shafts that were used during construction, and which will be permanently lined and used for ventilating purposes. The rock met with was

blue and grey sandstone, horizontally stratified, with soft material between the stratifications. The earth met with in the tunnel was heavy clay and gravel. The sectional area of arched tunnel down to subgrade is 660 square feet; sectional area above the track being 608 square feet (see Figure 4). The



LONGITUDINAL SECTION
NICHOLSON TUNNEL

Fig. 1.

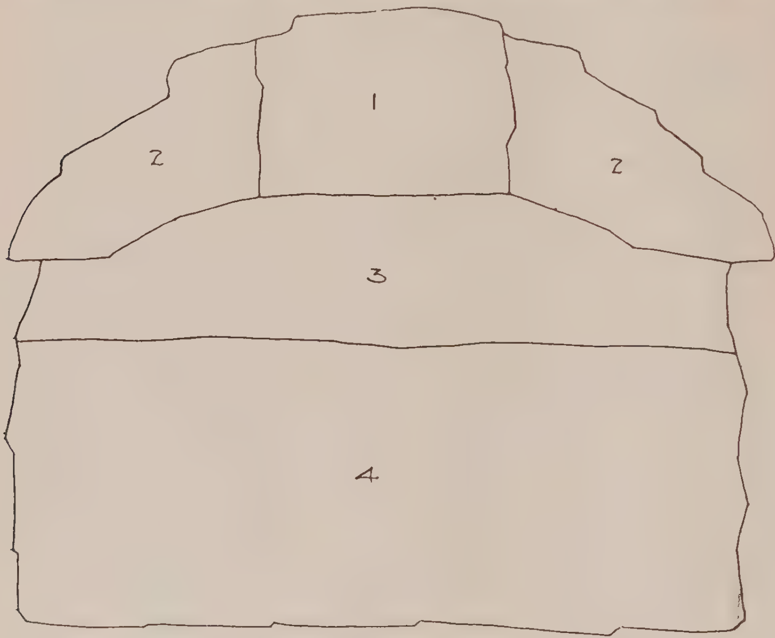
total area of the excavation removed approximated 964 square feet, equivalent to 35.7 cubic yards per lineal foot of tunnel.

The work was started by sinking Shaft No. 2, September, 1912, the excavation of this shaft being completed, April, 1913. Shaft No. 1 was started October, 1912, and completed June, 1913. About 0.58 lb. of dynamite was used per cubic yard of excavation in shafts.

The local cost of the shaft excavation was divided, approximately:

Labor	67%
Repairs and Miscellaneous	9%
Supplies, including explosives	24%

Each shaft was sunk to a point about twelve feet below the top of the tunnel, and drifts or headings were then started.



EXCAVATION IN ROCK
NICHOLSON TUNNEL.

Fig. 2.

Figure 2 shows the general method of construction, the top center heading method being followed; the headings being worked in two directions from each shaft, and also from the west end.

Headings (marked Sec. 1, Fig. 2) were started in both directions from both shafts, working two ten-hour shifts per day of twenty-four hours, in each of the four headings, with an average progress of slightly less than eight feet per day in

each heading. A heading, occupying the same position in the section, was started at the west portal in September, 1913, with approximately the same rate of progress. The number of holes drilled per shift in each heading varied from 18 to 24, each having an approximate depth of 8 feet. There were always 8 cut holes; the number of others varied with kind of material encountered. Average cost of drilling was 29 cents per foot drilled. The amount of material removed per lineal foot of heading from each of the five headings where work was in progress was about 5 cubic yards per lineal foot of tunnel. The second step in the process of tunnel excavation was the removal of sections marked 2 (Fig. 2), this work being done close behind the removal of the heading. Where the material was poor, Section No. 2 was not excavated until the advanced headings were joined, and the timbering was carried up immediately behind this excavation.

The cost of explosives per cubic yard of heading was 78 cents. The total cost of the heading, by percentages, was:

Labor	68.3%
Repairs	1.5%
Supplies, including explosives	26.6%
Miscellaneous	3.6%

Top bench (marked 3, Fig. 2) was drilled, shot and thrown by hand over top of main bench to the shovel, one shift ahead of the drilling of main bench (marked 4, Fig. 2). All the material from both benches was removed by a No. 40 Marion shovel operated with compressed air.

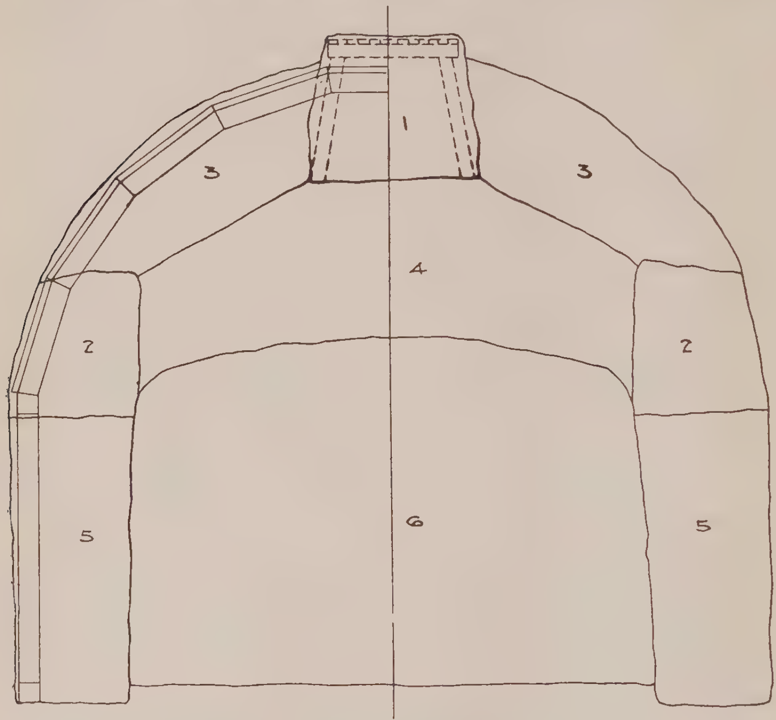
In November, 1913, the shovel started to excavate Sections 3 and 4 (Fig. 2) at the west portal, and reached Shaft No. 1 in July, 1914.

From a point 790 feet east of Shaft No. 1 to the east portal, a distance of about 400 feet, soft material was met with and a different plan followed. A shaft 8 ft. by 10 ft. was sunk near east portal and all the material, excepting Section 6 (Fig. 3), was handled through it. A small top heading was first driven and temporarily timbered. (See Section 1, Fig. 3.)

Section 2 (Fig. 3) was then removed and wall plates set, and this was followed immediately by the excavation of No. 3 and rings of timber were erected.

Sections No. 5 (Fig. 3) were then excavated and mud sills and plumb post placed. Lastly, Section 6 was removed by the shovel. The excavation was finished November 14, 1914.

The entire tunnel was timbered, as is shown in detail (Fig. 4). Timbering was necessary throughout, the timber arches



EXCAVATION IN SOFT GROUND
NICHOLSON TUNNEL.

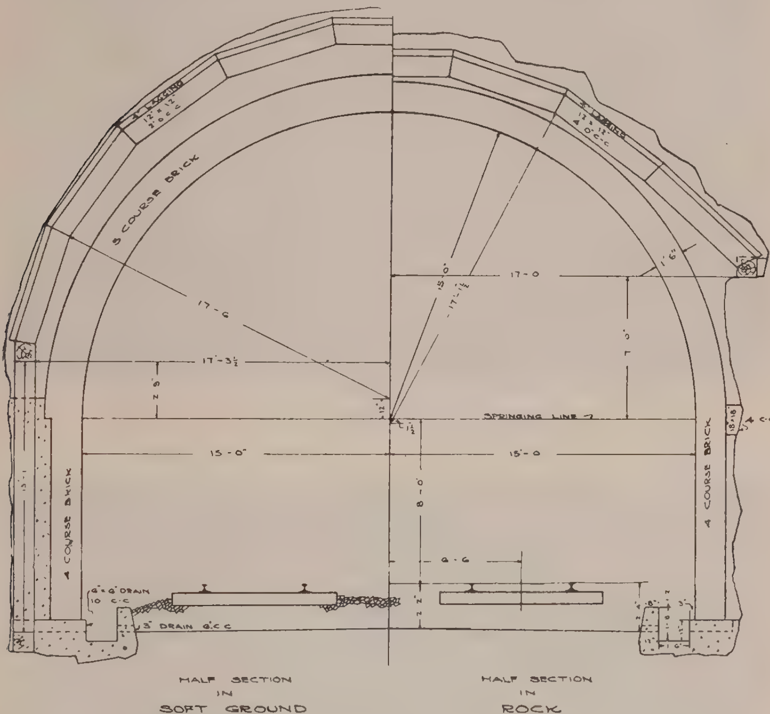
Fig. 3.

being spaced from two to four feet apart, depending upon the character of roof.

In taking out the bench, approximately one pound of 60% dynamite was used per cubic yard excavated, and the shovel made an average of 11.6 lineal feet of tunnel per 10-hour shift. The cost of trimming and ditching in the tunnel amounted to about eight cents per yard for the total yardage of the tunnel.

The tunnel is now being lined with hard-burned brick side

walls and arch. The side walls were started September 14, 1914, and the arch September 29, 1914, and have been progressing at the rate of thirteen lineal feet per day. Electric power is used for lighting, for mixing mortar and operating the elevator to lift brick from grade to spring line of arch.



NICHOLSON TUNNEL

Fig. 4.

Fig. 5 shows east portal of tunnel in the wide cut made for three and four tracks.

Fig. 6 shows the timbering preliminary to brick-arching in rock section.

Fig. 7 shows the timbering in soft material, with bulk-head erected for the purpose of permitting the construction of masonry during freezing weather.

Fig. 8 shows brick side walls and arch, with movable centers, used during construction of lining.

Fig. 5. East Portal of Nicholson Tunnel, D. L. & W. R. R.

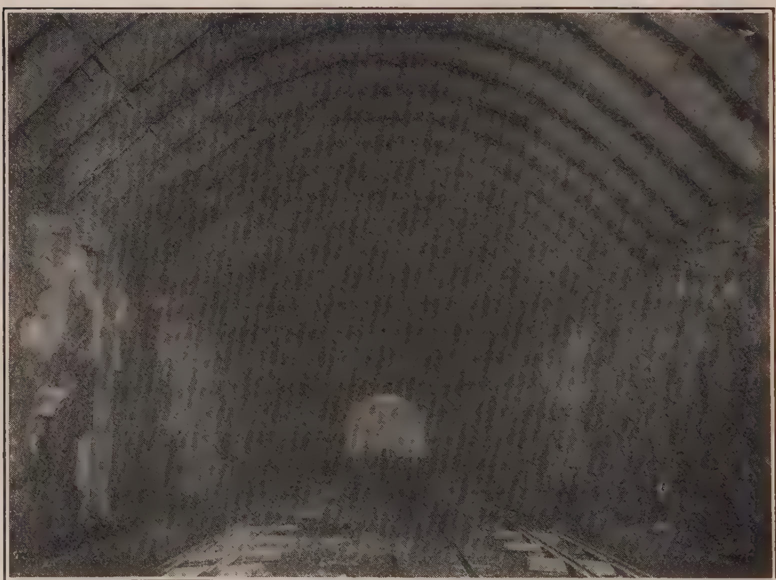


Fig. 6. Nicholson Tunnel, D. L. & W. R. R.

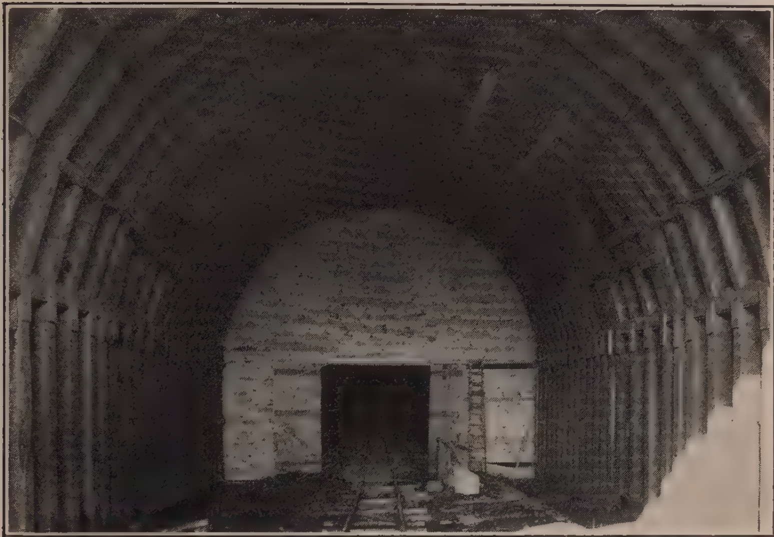


Fig. 7. Nicholson Tunnel, D. L. & W. R. R.

Fig. 8. Nicholson Tunnel, D. L. & W. R. R.

MOUNT ROYAL TUNNEL.

For the Montreal Terminal of the Canadian Northern R. R.

A double-track tunnel, length, 17.000 feet, completed in 1914, for reaching Terminal Station at Montreal. The tunnel has two tubes, each 13 ft. 6 inches wide; 18 ft. 4 in. high above track; total size of the excavation for the two tracks being generally 31 ft. wide, 23½ ft. high, the tunnel having been designed and constructed for the use of electric power only.

The character of the rock was Trenton limestone and igneous rock.

The tunnel section required the removal of about twenty-six cubic yards of material per lineal foot of tunnel. The reinforced concrete lining afterwards inserted converted this section into two single-track tubes, each having a sectional area of 207 sq. ft. above rails.

The method adopted for excavation was the bottom center-heading type, size of heading being 10 ft. high, 14 ft. wide, requiring the removal of about five cubic yards per lineal foot of heading constructed. In the heading, eighteen to twenty-four holes, from five to eight feet deep, were drilled while the muckers were removing the material accumulated from the previous blast, this work being expedited by the use of steel plates placed on the bottom of the heading before each blast, so that the muckers shoveled from a smooth surface. The process of drilling holes and removing the muck was completed in eight-hour shifts. In good material, as many as six rounds of shots were fired in the headings each day. The average progress in each heading was about 420 feet per month, omitting extraordinary delays, or at the rate of 13½ feet per day of twenty-four hours; and on some days the average excavation in heading reached 93 cubic yards per day of twenty-four hours.

The method of procedure was, first, to construct the heading. Second, at distances not less than 500 feet apart, break-up sections to roof of tunnel were made above the heading to the full width of the tunnel; the heading having first been heavily timbered for receiving the material dropped down, which was later passed through the timber cover to cars in the heading. Third, from these break-up sections the excavation was carried

forward in both directions up to the roof by breaking down the material directly over the heading, which had been continuously timbered, as noted above, and by passing the material through openings in heading timbers to cars in the heading, at grade. Fourth, to wing out the upper half of the tunnel to the full width. Fifth, to widen out the bottom part of the tunnel to the full width with a shovel operated by compressed air.

The excavation following the heading was generally done as rapidly as the heading, for the reason that there were available several points for attacking the excavation over the timbered heading.

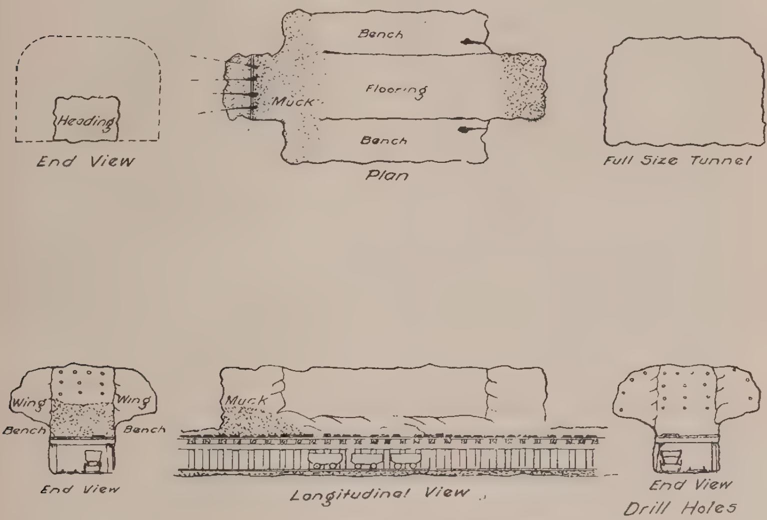


Fig. 9. Mt. Royal Tunnel, Canadian Northern Ry.

Fig. 9 shows the steps described in making the tunnel excavation. It will be noted that each break-up section furnished two additional faces for attacking the excavation above the heading, drilling in each of these two faces being undertaken alternately while the loose material is being removed from the opposite face after a blast. With one main heading and four break-ups at the west end of the tunnel, the average excavation was about 500 cu. yds. daily, equivalent to 19 ft. of completed tunnel section per day at one end alone.

SEATTLE TUNNEL.

For Terminal Entrance of the Great Northern Railway and Northern Pacific Ry. at Seattle.

Double-track tunnel of 5141 feet length, having an inside width of thirty feet, as fully shown on Plan "H". This plan also shows in outline the methods used in the excavation of about 45 cu. yds. of material per ft. length of tunnel.

The material in which this tunnel is located is a heavy blue clay. The excavation was conducted without the use of a shield, under methods outlined on the plan referred to. The method of driving the tunnel from both ends was somewhat different from that usual in such work, as five drifts were used (all indicated on the left-hand side of Plate VI), each being 10x10 feet in section. The two bottom drifts, left and right, were located at subgrade along the sides of the tunnel and were started first, being kept from ten to twenty feet in advance of the drifts directly over these two. The topmost drift, in the center at the top of the tunnel, was advanced at the same rate as the second two drifts. As the work on each of these drifts progressed, 12-x12-inch timbers were used to shore up the roof and the permanent timber lining for the sides of the tunnel was put in place. After the side and top drifts had advanced about 100 feet, the triangular cores remaining between No. 2 side drifts and the top center drift were removed, and the roof shored up to the crown of the arch as this work progressed. The concrete lining in the side walls was kept constructed close up to the headings of the side drifts. Following about 100 feet in the rear of the gangs employed on this concreting work, other gangs were employed in stoping out the main central core of the excavation. The excavation was done almost entirely with pick and shovel. No blasting whatsoever was required in the tunnel. The material was handled in wheelbarrows, traveling belts and contractors' cars. The progress of the work is shown on Plate VII, which plan also shows the alignment and profile of the tunnel. This plan shows that the work was started at the north portal on May 17, 1903, and the excavation was completed January 14, 1905.

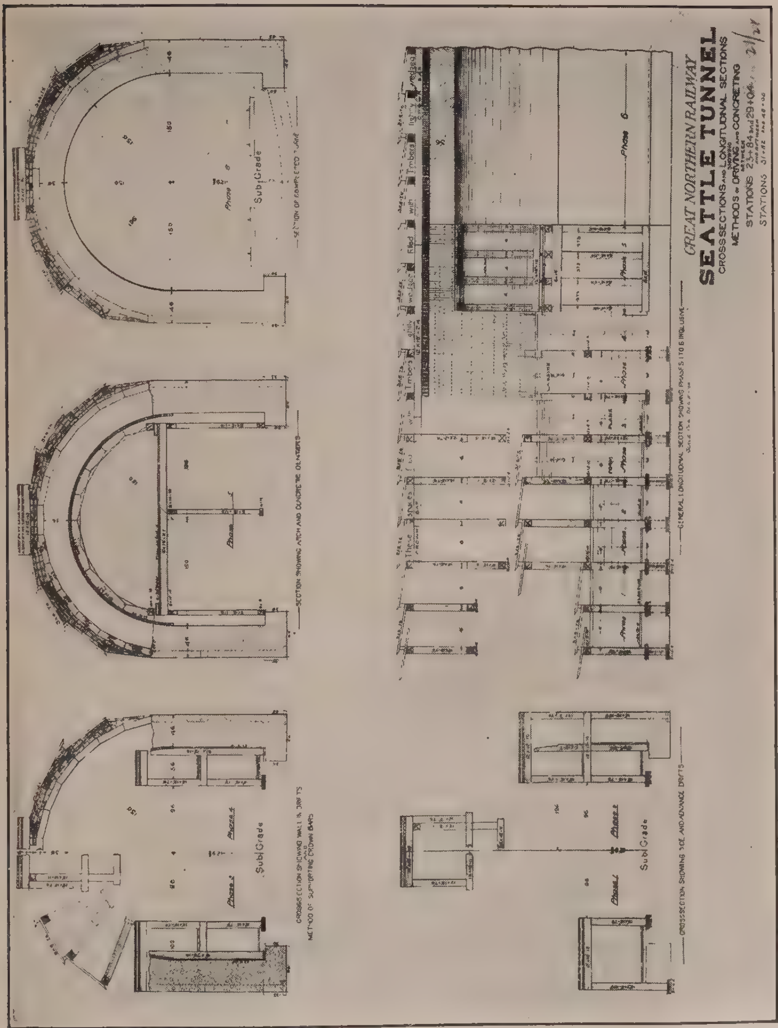

GREAT NORTHERN RAILWAY
SEATTLE TUNNEL
CROSSSECTIONS AND LONGITUDINAL SECTIONS
SHOWING
METHODS OF DRIVING AND CONCRETING
Sub Grade

Plate VI.

ROGERS PASS TUNNEL.

On Change of Line between Beavermouth and Cambie, across the Selkirk Mountains, at Rogers Pass, on the Canadian Pacific Railway.

A double-track tunnel, 26,400 feet long, work on which is now in progress, in connection with the construction of a double-track line having lighter grades than the present one across the Divide. The object of this work is to reduce the elevation of the summit 540 feet; shorten the line four and a half miles; and eliminate 2400 degrees of curvature, four and a half miles of snow-sheds, and some very heavy bridging.

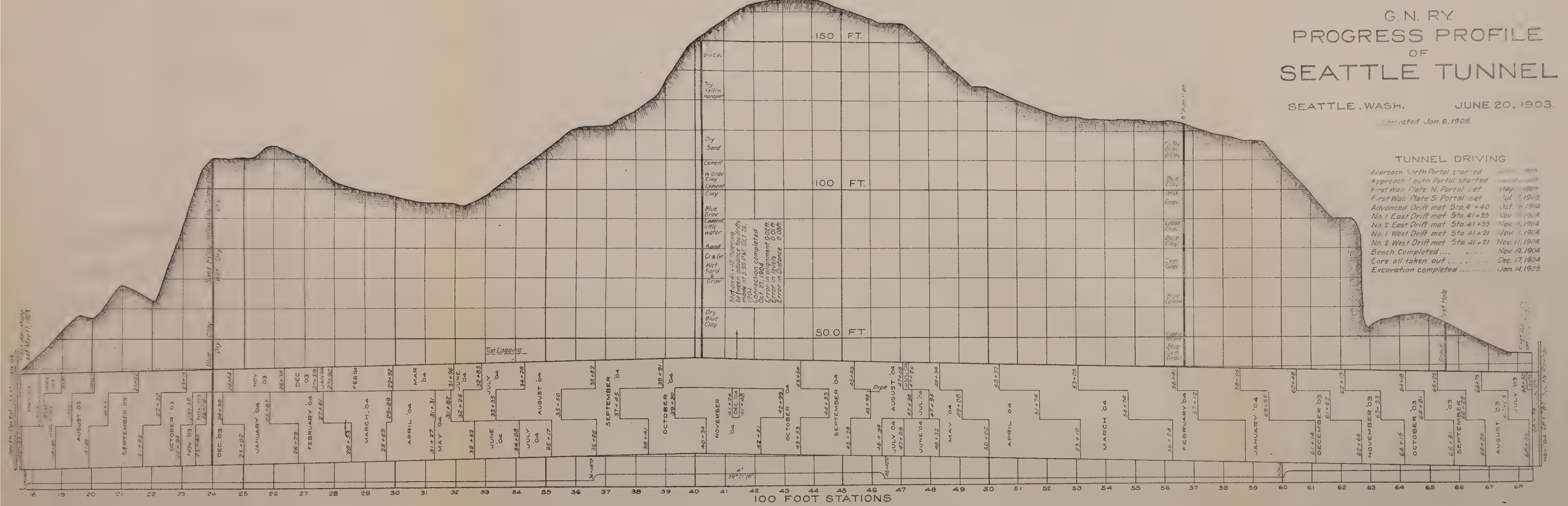
The materials so far met with, beyond the earth line at the ends, have been slates, schists and quartzite.

Plate VIII shows the location.

Plate IX shows the tunnel in profile, general cross-section and longitudinal section, illustrating the method of conducting the work.

Plate X shows the cross-section of completed tunnel, upon which diagram the estimated figures appear showing that 30.76 cu. yds. of material must be moved per lineal foot of tunnel, where timber lining is required. The area of the completed section above track where timber lining is used will be 626 sq. ft., and where masonry lining is built this area will be 526 sq. ft.

Plate IX shows the method being followed in the construction of this tunnel, by the use of pioneer drifts located 50 ft. to one side of center of tunnel. This is followed by the construction of a main heading 11 ft. wide and 8 ft. high, nearly in the center of the tunnel section in both earth and rock. At the ends of the tunnel, where earth existed, the construction of the main heading was followed by bottom subgrade drifts at the left and right sides of the tunnel; then by a crown drift 9 ft. by 10 ft.; and, lastly, by drifts at the left and right sides of the tunnel above those at subgrade, material excavated therefrom being handled by cars in the lower level. The main heading, throughout, is being connected at points one-half mile, more or less, apart to the pioneer drift, which pioneer drift will furnish the means, during tunnel construction, for ventilation, carrying all air pipes, water pipes, other appliances and supplies. It will also be used as a means for conveying ma-



G. N. RY.
PROGRESS PROFILE
OF
SEATTLE TUNNEL
SEATTLE, WASH.
JUNE 20, 1903.
Jan. 6, 1905
TUNNEL DRIVING
Advanced Drift met Sta. 4 +40
No. 1 East Drift met Sta. 41+33
No. 2 East Drift met Sta. 41+33
No. 1 West Drift met Sta. 41+21
No. 2 West Drift met Sta. 41+21 Nov. 11, 1904.
Bench Completed Nov. 19. 1904
Core all taken out Dec. 17, 1904
Excavation completed Jan. 14, 1905
150 FT.
100 FT.
50.0 FT.
Top Lagging
100 FOOT STATIONS

Plate VII.

terial excavated from the center heading to a point in the main tunnel back of the shovels, which are operated by compressed air.

The main object sought by the contractor through the construction of this pioneer drift was the securing of increased speed in the tunnel excavation and a decrease in the expense, through ability to attack the excavation at several points at the same time and permit of the continuous operation of the shovels without danger of breaks in the air lines, or serious interruptions from other causes. The saving of time in this construction is considered very important by the railroad, as well as by the contractor; and a value has been placed by the railroad for each day saved. The contractor anticipates that this method of construction will result in such a saving of costs in the tunnel excavation that the saving, when combined with the time bonus received, will far exceed the cost of the pioneer drift.

The construction of the tunnel was begun in September, 1913. At date of December 1, 1914, the pioneer drift had reached a point 5663 feet from the east end, and the second pioneer drift had reached a point 3160 feet from the west end —the distance between the pioneer drifts being 16,020 feet.

On December 1, 1914, the main central heading had reached a point 3094 feet from the east end, and 2073 feet from the west end. At the east end the shovel working on full section had advanced 1080 feet, where rock was encountered. During the latter part of December this shovel was working in a full rock section. At the west end, on December 1, 1914, 180 feet of the main tunnel had been timbered and the shovel had advanced 15 feet in taking out full tunnel section.

On January 1, 1915, the pioneer drifts (see Plate IX) were 13,935 feet apart, progress during one month having been 2085 feet. The main central heading, on same date, was 3678 feet from east end and 2860 feet from west end, progress during one month having been 1381 feet. The shovel, working out full section, had reached a point 1488 feet from east end and 225 feet from west end, the progress during this one month having been 618 feet.

At the end of January, 1915, one of the hard winter months, the pioneer drifts (see Plate IX) were 13,506 feet apart.

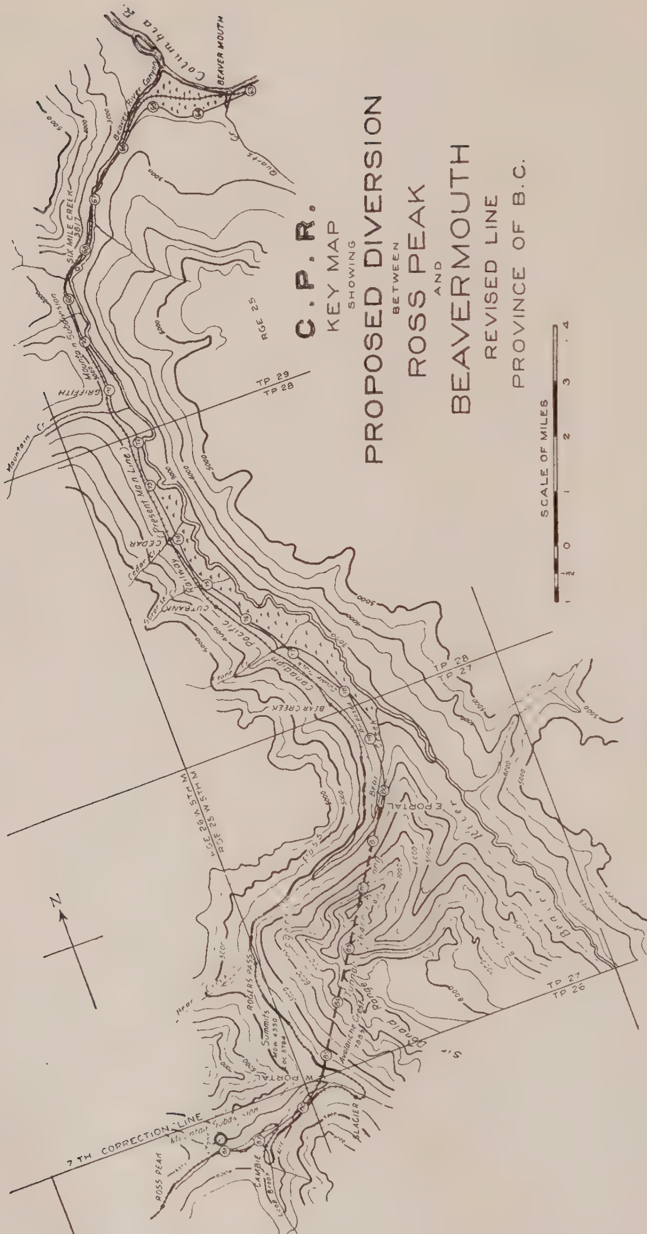
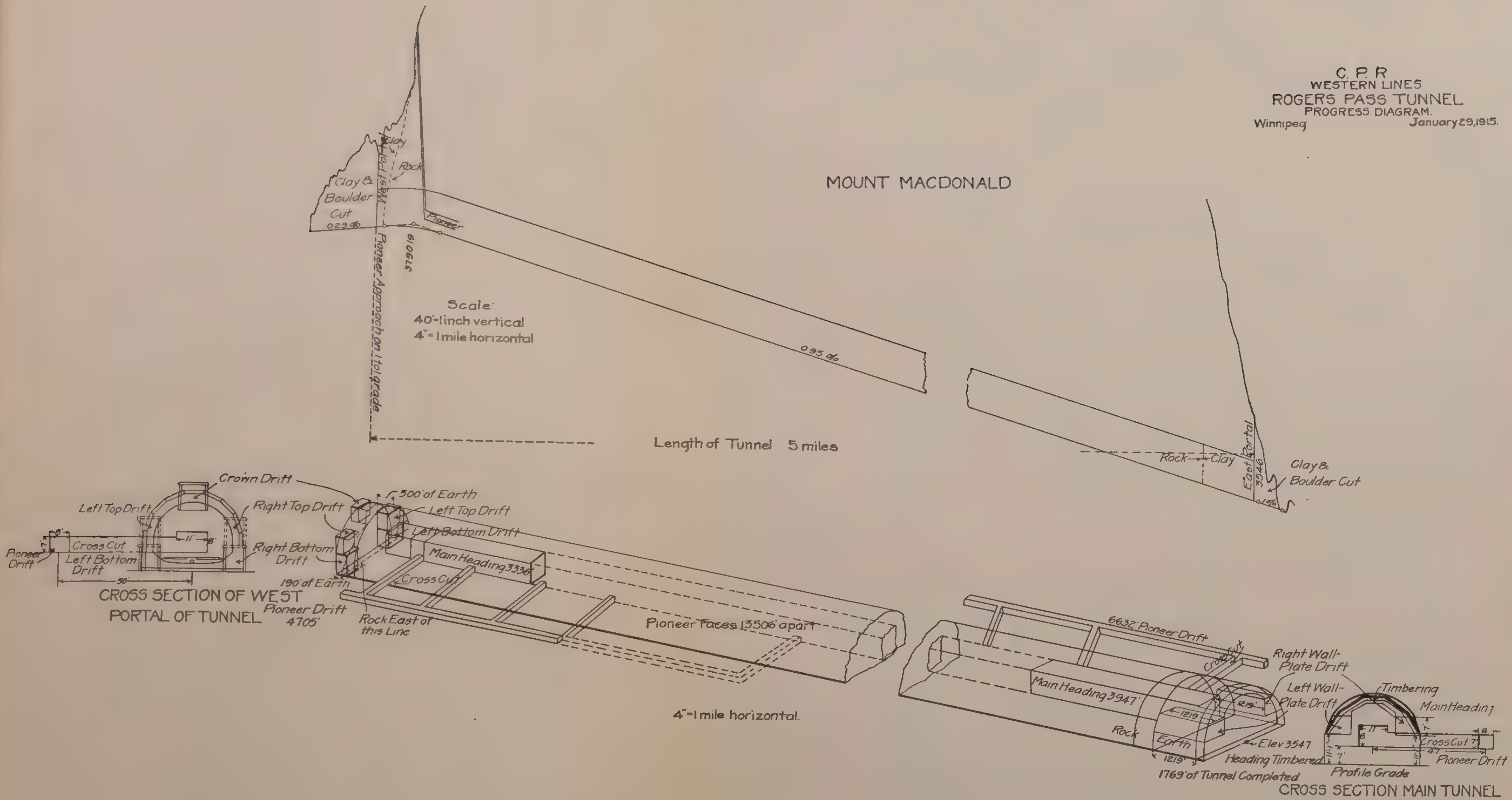


Plate VIII. Rogers Pass Tunnel.



C.P.R
WESTERN LINES
ROGERS PASS TUNNEL
PROGRESS DIAGRAM.
Winnipeg
January 29, 1915.
MOUNT MACDONALD
Clay & Boulder Cut
0.29%
West Portal
Clay
Rock
Pioneer
Pioneer Approach on 1 to 1 grade
3790.19
Scale:
40'=1 inch vertical
4"=1 mile horizontal
0.95%
Length of Tunnel 5 miles
Rock
Clay
East Portal
3546
Clay & Boulder Cut
1%
Crown Drift
Left Top Drift
Right Top Drift
Cross Cut
Left Bottom Drift
Right Bottom Drift
Pioneer Drift
CROSS SECTION OF WEST PORTAL OF TUNNEL
500' of Earth
Left Top Drift
Left Bottom Drift
Main Heading 3336'
Right Bottom Drift
190' of Earth
Cross Cut
Pioneer Drift 4705'
Rock East of this Line
Pioneer Faces 13506' apart
4"=1 mile horizontal.
6632' Pioneer Drift
Cross Cut
Right Wall-Plate Drift
Left Wall-Plate Drift
Main Heading 3947'
1219'
Rock
Earth
Elev 3547
Heading Timbered
1769' of Tunnel Completed
Timbering
Main Heading
Cross Cut
Pioneer Drift
Profile Grade
CROSS SECTION MAIN TUNNEL

Plate IX.

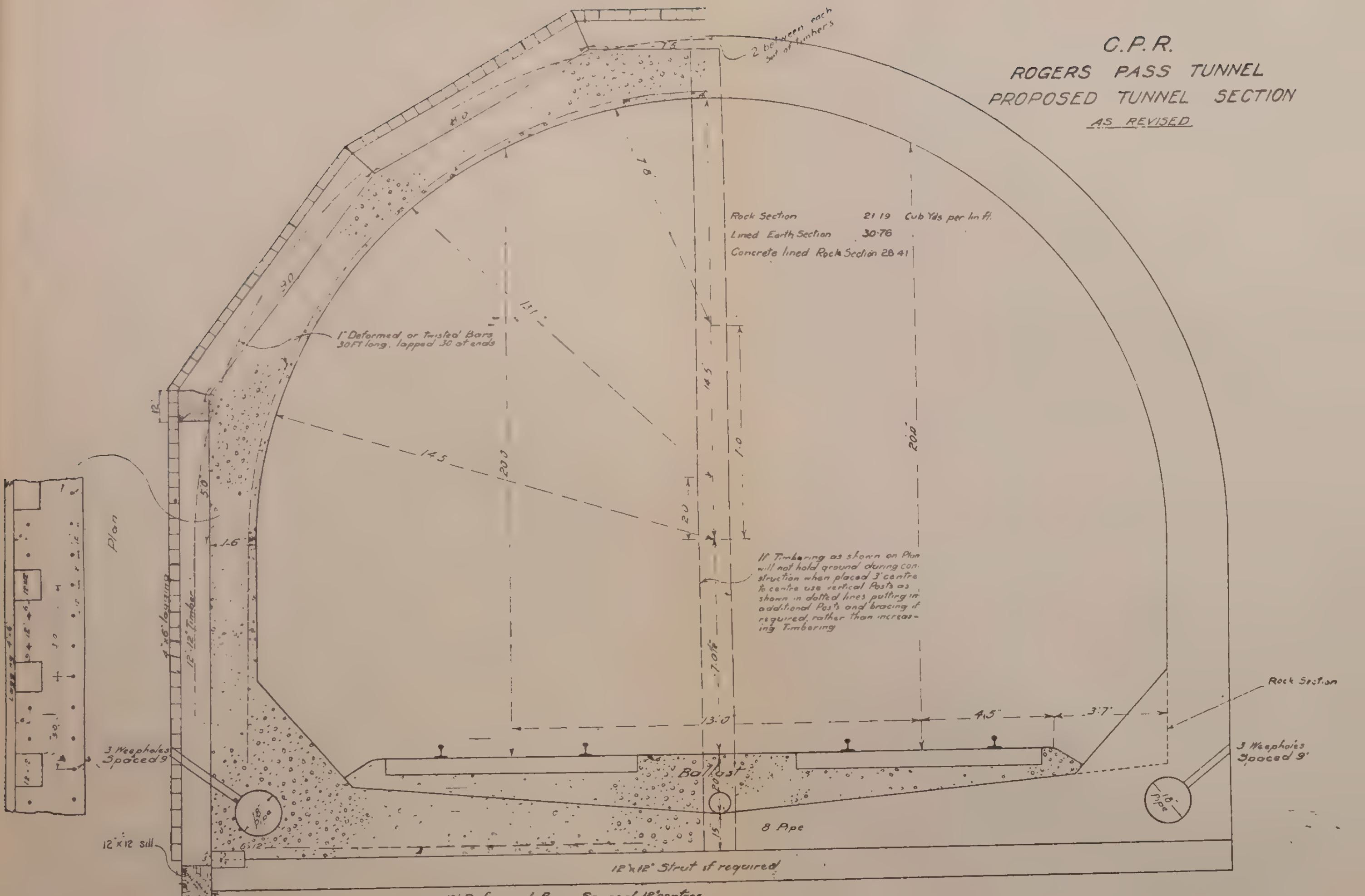
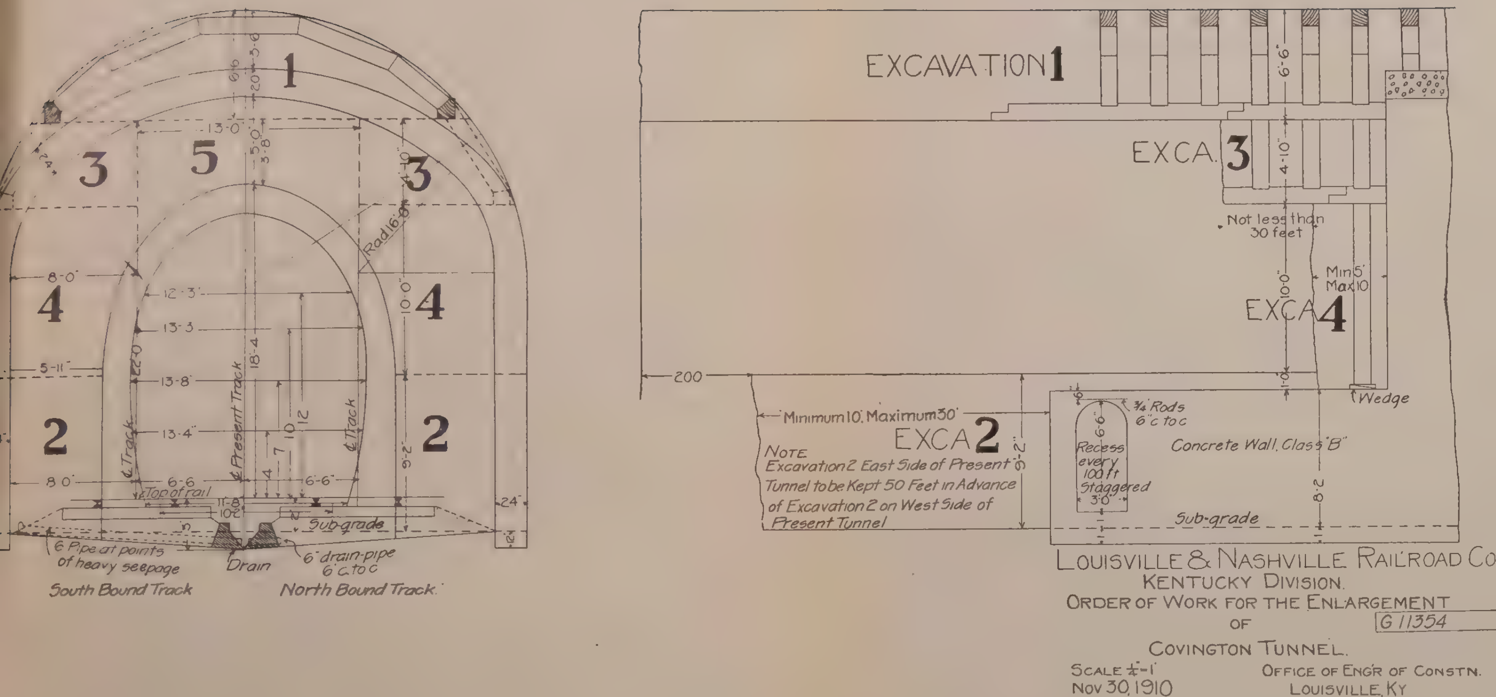


Plate X. Completed Tunnel Section.



South Bound Track
North Bound Track.
6" Pipe at points of heavy seepage
Drain
6" drain-pipe 6' c. to c.
Sub-grade
Present Track
Track
Top of rail
Rad 16'-8"
EXCAVATION 1
EXCA. 3
EXCA. 4
EXCA. 2
Not less than 30 feet
Min 5' Max 10'
Minimum 10', Maximum 30'
¾" Rods 6" c. to c.
Wedge
Recess every 100 ft Staggered
Concrete Wall, Class "B"
Note
Excavation 2 East Side of Present Tunnel to be Kept 50 Feet in Advance of Excavation 2 on West Side of Present Tunnel
Louisville & Nashville Railroad Co
Kentucky Division.
Order of Work for the Enlargement of Covington Tunnel.
G 11354
Scale ¼"=1'
Nov 30, 1910
Office of Eng'r of Constn.
Louisville, Ky

Plate XI.

The main central heading on same date was 3947 feet from the east end and 3336 feet from the west end of the tunnel. The shovels working out full section had reached points 1769 feet from the east end and 375 feet from the west end.

The section of the pioneer drift requires the removal of about 2.1 cu. yds. per lineal foot of advance.

The section of the main central heading of the tunnel requires the removal of about 4 cu. yds. per lineal foot of advance.

The progress on each of the central headings has been at the rate of about 22 feet per day in rock; the advance secured by each round of shots being about 6 feet. Under this plan of working in rock section the total amount of material which is moved by hand per foot of total advance is about 6.1 cu. yds., made up of pioneer drift and main central heading. This material is taken out in small cars, through the pioneer and connecting drifts, to points in the completed tunnel behind the two shovels, and is removed by regular tunnel cars. The main part of the tunnel section is excavated by the two shovels loading into tunnel cars, which are handled through the completed tunnel, the maximum haul beyond the ends of tunnel being two miles. Drilling and blasting the rock is conducted from the central heading, the holes being drilled radially therefrom in lengths approximating 30 feet of tunnel at one shot; and it is estimated that, on account of good ventilation and lack of obstructions of any kind in the central working heading, a round of shots in this length can be made in approximately 16 hours.

COVINGTON TUNNEL.

On Louisville & Nashville Railroad.

Enlarged from a very small single-track section with a maximum width 13 ft. 8 in., to a double-track section equivalent to that of the standard proposed by the American Railway Engineering Association.

The original tunnel was constructed about the year 1852 (no records of which exist), and was 754 feet in length. It had a very small section, as indicated on Plate XI. It was lined partly with brick and partly with stone masonry of varying thickness. As this tunnel was located close to Covington Yard, a considerable switching movement was handled at all

times through the tunnel, and it was constantly filled with smoke. The tunnel was driven through a peculiar formation; about 85% of the material was an indurated clay, or so-called soapstone, separated at intervals by thin ledges of hard limestone.

It was necessary to construct the enlargement in such a manner as to keep the tunnel open for traffic, and the diagram on Plate XI shows the order of procedure that was approximately followed; the general plan being to let the old masonry lining remain as far as possible to act as a smoke shield.

Excavation No. 1, the upper heading, was begun at the south portal and carried continuously, night and day, until completed. The arch timbering above Excavation No. 1 was carried forward as the excavation progressed, being kept up close to it. It was found necessary to take out a greater amount of excavation, in this process, than is indicated in the diagram. The two parts, one numbered 3 and one numbered 5, were being taken out with No. 1.

After good progress had been made on Excavation No. 1, Excavation No. 2 and part of Excavation No. 4 were taken out. The last step in the excavating was to complete that around the old masonry.

The work was begun in February, 1911. In July, 1911, an accident happened to part of the old masonry, due to its being struck by a car, and the removal of the old arching was undertaken in the month of August and carried to a completion, a light timber shield being put in its place to protect the men from smoke while constructing the lining of the new tunnel.

No heavy blasting was required in removing the material for enlarging this tunnel. The plan of the completed lining does not show the reinforcing bars which were used in the section throughout the tunnel.

TUNNELS ON THE GRAND TRUNK PACIFIC RAILWAY.

Figs. 10, 11 and 12 are attached as best showing the methods used by the Grand Trunk Pacific Railway for permanently lining single-track tunnels constructed in yielding material and originally lined with timber.

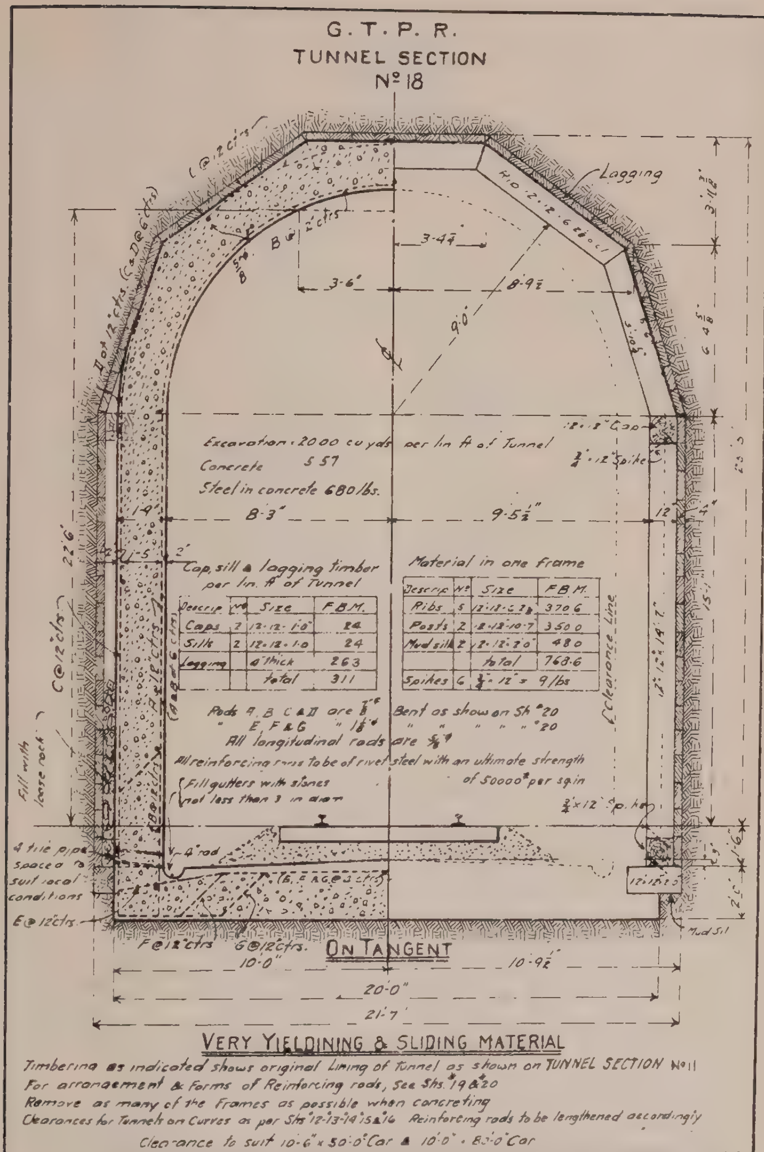


Fig. 10. Concrete Tunnel Lining, Grand Trunk Pacific Ry.

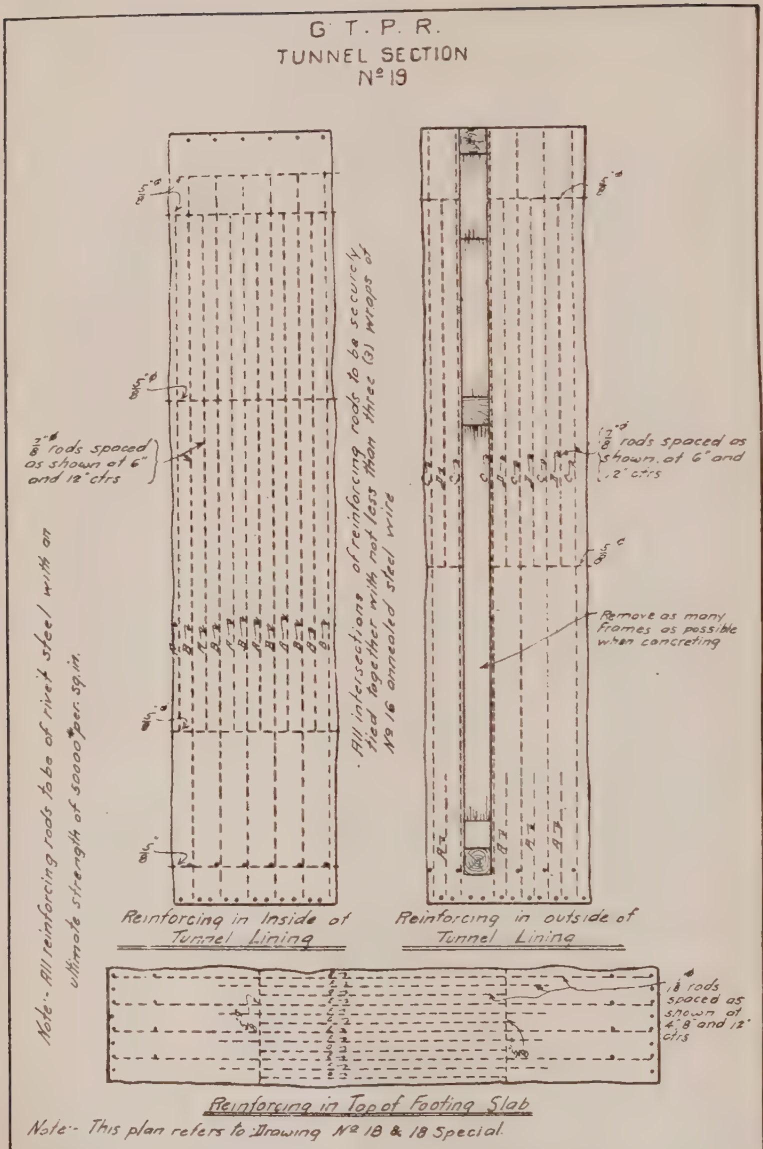


Fig. 11. Reinforcing Details for Concrete Tunnel Lining, G. T. P. Ry.

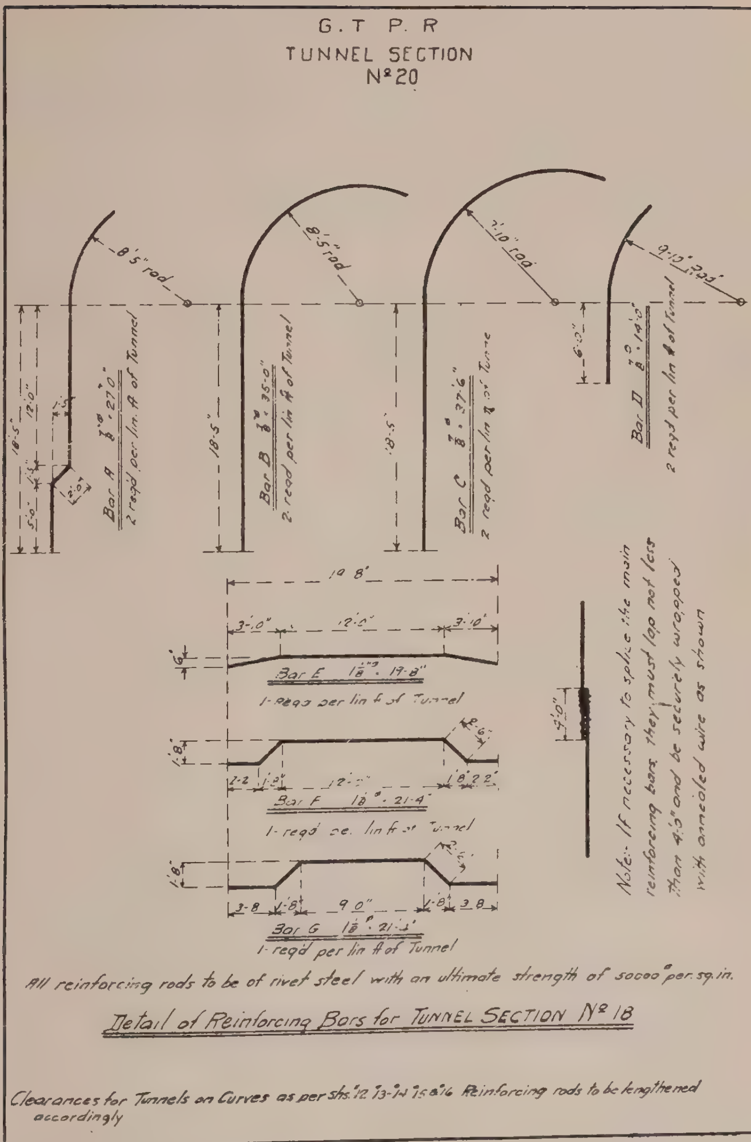


Fig. 12. Details of Reinforcing Bars, Concrete Tunnel Lining, G. T. P. Ry.

CONCLUSION.

The plan most generally used in excavating tunnels in hard material or rock, in the United States, whether single- or double-track, is the top center-heading method as shown in Fig. 2 of Plate V of the Sandy Ridge tunnel, and in Fig. 2 of the Nicholson double-track tunnel.

The method used in the Snoqualmie tunnel was the bottom-heading method, the bottom-heading being driven on one side.

The method used on the Mount Royal tunnel was the bottom central-heading. The method being used on the Rogers Pass tunnel is a parallel pioneer drift, followed by a tunnel heading located near center of the tunnel section.

As all of these tunnels were constructed chiefly in rock of varying degrees of hardness, as described, it seems well to compare the progress and determine the reasons for the most favorable results. In future tunnel construction, the best methods for securing maximum speed at minimum costs, with the latest forms of appliances, may probably be selected more readily than heretofore.

The detailed data and plans from which this summary has been deduced were furnished by the following parties:

Snoqualmie Tunnel..................Mr. C. F. Loweth, Chief Engineer, Chicago, Milwaukee & St. Paul Railway.

Sandy Ridge Tunnel..............Mr. Ward Crosby, Chief Engineer, Carolina, Clinchfield & Ohio Ry., and Rinehart & Dennis Co., contractors of tunnel.

Nicholson Tunnel....................Mr. J. G. Ray, Chief Engineer, Delaware, Lackawanna & Western Ry., and Mr. D. W. Flickwir, contractor of the tunnel.

Mt. Royal Tunnel....................Published description in pamphlet by Mackenzie, Mann & Co., Ltd., contractors of tunnel.

Seattle Tunnel..........................Mr. A. H. Hogeland, Chief Engineer, Great Northern Railway.

Rogers Pass Tunnel...............Mr. J. G. Sullivan, Chief Engineer, Canadian Pacific Railway.

Covington Tunnel....................Mr. W. H. Courtenay, Chief Engineer, Louisville & Nashville Railroad.

G. T. P. Ry. Tunnel...............Mr. H. A. Woods, Assistant Chief Engineer.

COMPARATIVE DATA ON TUNNELS.

Items.	1 SNOQUALMIE	2 SANDY RIDGE	3 NICHOLSON	4 MT ROYAL	5 ROGERS PASS
Character of Material	Black Slate Quartzite Conglomerate	Sandstone and Slate	Hard Sandstone with Slate Partings	Limestone and Dikes of Igneous Rock	Slates, Schist and Quartzite
Length Ft	11890	7804	3630	17000	26400
Number of Tracks	1	1	2	2	2
Neat Area Finished Sec. Sq Ft.	352	378	660	414	526
Area Sec. Excavated. Sq. Ft.	517	625	964	702	831
Cu. Yds. Excavated Per Lin. Ft.	19.2	23.0	35.7	26.0	E. 30.76 S.R. 25.0
Heading - Location of	Bottom-Side	Top-Center	Top-Center	Bottom-Center	Central + Pioneer Drift Outside
Heading - Cu. Yds. Per Lin. Ft.	4.0	3.1	5.0	5.0	4.0 (+2.1)
Heading - Av. Daily Prog. Each Ft.	9.5	7.5	8.0	13.5	20.6
Heading - Max. Number Worked	2	2	3	3	2
Heading - Number Holes Drilled	14 to 30	22 to 24	18 to 24	18 to 24	26 to 32
Heading - Depth of Holes - Ft.	9	10	8-10	5 to 8	6
Heading - Av. Break Per Shot	6.1	7.5	7.5	5.0	6.0
Shafts, Number	0	0	2	2	0
Bench - Method of Removing	Break up 150' apart hand and shovel.	Sub-bench and shovel.	Sub-bench and shovel.	Break up 500' apart hand and shovel.	
Bench - Av. Daily Progress Each, Ft.	7.7	7.5 ②	11.6	13.5	23.6 {5 mo. to Sept. 1-'15
Full Sec. Av. Daily Progress, Ft.	12.7 ①	10.4	7.4 ③	19.2	47.3 {5 mo. to Sept. 1-'15
Pounds 60% Dynamite Per Cu. Yd.	2.8	4.0	1.7	2.23	3.0 in hard slate
Pounds 60% Dynam. Per Ft Tunnel	55.25	93.33	60.7	58.0	75.0 in hard slate
Excess Exc. Per Ft. Tunnel - Cu. Yd.	3.5	5.0	3.7	—	3.0

1 Total time in two headings. 27½ months. Total average daily progress in headings 144' ①
General average progress in each bench when working = 9 ft per day. ① June 1912 to Dec 1912

2. Heading started Oct 1912, out May 1914 = 19 months. Bench started Nov 1912, out Nov 1914
24 mo. ② General average progress in 2 benches distributed over whole period = 11 ft per day {Prices Tun'l Ex 3.15 Falls 1.00

3 Two shafts total ft. 237' used = 16116 cu. yds Started Sept 1912, finished in 7 mo.
Heading work 15739 cu yds - completed Sept 1914 - Bench started Nov 1913, completed in 12 mo {Price for all tunnel & shaft exc. [illegible]
③ Tunnel required 16½ mo. after completing shafts - av'g. daily progress 7.4 ft.

4 Maximum of 4 breakups used in heading
In 15 mo. all headings completed and 1½ mile breakups

5 Max. heading progress at one end in a month was in Jan. 1915 - 932 ft. = 30 ft per day
Max. full section progress at one end in a month was in Aug. 1915 - 827 ft. = 26.7 ft per day.
Full section removed by drilling 26 radial holes in rings spaced about 5 ft apart,
firing about 6 rings consecutively.
⑤ In hard schist this increased to 5 lbs.

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Mt. Royal Tunnel, Railway Review, Dec. 12, 1914, Vol. 55, p. 710.

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DISCUSSION

Mr. Hood. **Mr. William Hood,**† M. Am. Soc. C. E., referring to the discussion of the tunnel section on the second page of the paper, said that the width of a tunnel is controlled, in general, by the largest size cars and engines operated on the line, and also by the convenience of the trackmen. But, more important still, it has been found that, in general, a tunnel 16 to 17 ft. wide can be constructed for the same cost as one 14 to 15 ft. wide. The reason is that work is more economically done in the wider tunnel. The Southern Pacific Co. up to some time in the 90's used to build tunnels 14 ft. wide at sub-grade and 16 ft. wide at the springing line. This section was changed to 17 ft. clear inside for the same price, the contractor being glad to adopt the larger section. This road now builds tunnels of 17 ft. clear width.

Mr. Cattell. **Mr. W. A. Cattell,*** M. Am. Soc. C. E., stated that all of the tunnels on the Western Pacific Railway, 44 in number and aggregating 45,350 ft. in length, were constructed 17 ft. wide; (1) to decrease first cost by permitting the use of a steam shovel during construction, (2) to secure better ventilation in operation and (3) to provide greater safety for employees engaged in track maintenance.

Mr. Sullivan. **Mr. J. G. Sullivan,**** M. Am. Soc. C. E., referring to the Rogers Pass Tunnel, said that the 46-ft. advance mentioned in the paper refers to both ends of the tunnel. For the last two weeks before he left, there was being made an advance of 55 ft. per day, or 27 ft. at either end of the tunnel. The pioneer drift is used for ventilation, air being forced from it into the main heading. The gases in the side headings are gotten out by the ordinary suction methods. This arrangement allows for almost continuous work by all of the men. Work can be continued in the heading while shooting at the bench.

He desired to ask if the figure of 0.58 lb. of dynamite per cubic yard of excavation in the shafts of the Nicholson Tunnel is correct.

Mr. Churchill. **Mr. Chas. S. Churchill** replied that this figure, 0.58, is correct; the local conditions made this possible.

† Chief Engineer, Southern Pacific Co., San Francisco, Calif.

* Consulting Engr., San Francisco, Calif.

** Chief Engr., Western Lines, C. P. Ry., Winnipeg, Man., Canada.

Mr. Sullivan.

Mr. Sullivan, replying to a request for information concerning the sort of pipe used for air ducts in the Rogers Pass Tunnel, said that ordinary 12-inch wooden pipe made for low water pressure had been used and this had given better results than galvanized iron pipes. The system is all one line with branches in the headings.

Steam shovels operated by compressed air were used; also compressed air locomotives with 12-yd. cars, and dinkey locomotives for small cars running into the headings. These latter are also operated by compressed air.

To a question concerning the type of drill employed, he replied that a light drill of the Leyner type had been used and that it had proved very satisfactory. Air and water under pressure are forced through the drill. One man can carry the drill in and out.

One of the objects of building the Rogers Pass Tunnel was to eliminate snow sheds, which were used not so much on account of the snowfall, as to take care of avalanches and slides, which are not uncommon.

The method used in constructing this tunnel is adaptable to rock that will stand without lining during construction. Shafts would accomplish the same result, but in this case the use of shafts was not feasible.

As to saving of time by this method, the best bids originally had were for completion in not less than 7 years; using this method, the contract was let for completion in 3½ years. The actual tunnel work will be completed in about 3 years.

By letter Mr. Sullivan said that regarding construction of Rogers Pass Tunnel, there is very little that he cared to add at the present time to what Mr. Churchill has said, excepting to note a few changes in plan and to advise progress up to date.

Plate X was a plan made before they had any experience in the soft ground. It was found, when soft ground was reached that considerably heavier timbering was required, and a seven-segment arch was used instead of a five. It was also found, however, that the 12 by 12 strut shown in the bottom of the tunnel was not required; therefore, in the lining, the solid invert of concrete was omitted; the weep holes are placed higher and run directly into a "V"-shaped trough in the concrete base. Struts of about the same section as the invert are placed between 20 ft. and 30 ft. apart to take care of strains caused by swelling of the earth which might take place.

Regarding the progress of the work, on July 25 work on the pioneer headings was stopped, when these headings were a little less than one mile (5202 ft.) apart, having been driven from the east end 10,740 feet, and from the west end, 8870. The total of these figures will not equal the total length of the tunnel on account of the pioneer tunnels being started at higher elevations than the tunnel proper and somewhat closer together than the portals of the tunnel. For the remaining mile of tunnel, the centre heading alone will be driven, and it is expected that this will be driven and the drilling for enlargement of same finished before the

Mr. Sullivan. shovels will reach the last cross cuts into the pioneer tunnel. As Mr. Churchill has stated, the main object of this method of driving the tunnel was to devise a cheap and rapid method of taking out the major portion of the rock by steam shovels. The steam shovels on August 19 were 16,488 feet apart, or about 3.12 miles.

Mr. Sullivan believes it will be admitted from the record of the past three months that the method is proving a success. The average monthly advance of the steam shovels has been 1636 feet; and as the contractors are always improving on methods, it is hoped to exceed this record before the tunnel is completed. The main headings in the centre of the tunnel on August 19 were only 4677 feet, or 0.89 miles apart. There have been twelve cross cuts made from the pioneer tunnel, six at each end.

A word of explanation may be necessary as to the equipment we are using: Mr. Churchill states that the excavation from the shovels is loaded into tunnel cars. These are ordinary standard-gauge 12-yard dump cars.

Mr. Courtenay. **Mr. W. H. Courtenay,*** M. Am. Soc. C. E., wrote that the Covington Tunnel described by Mr. Churchill is within the city limits. It was impracticable to drive a new tunnel on either side of the old tunnel on account of local conditions.

As about 170 engines passed through the tunnel daily, it was imperative that the method of constructing the double-track tunnel on the centre line of the old narrow tunnel provide for keeping the smoke and gas from locomotives from the men engaged on the work of enlargement. To accomplish this with minimum cost, it was decided to maintain the old single-track tunnel masonry until the enlargement of the section and construction of masonry lining for the double-track section could be completed.

The method indicated on Plate XI was devised by Mr. J. E. Willoughby, who was in charge of the work, for conducting it without interfering with the very frequent train movements through the tunnel, and for attaining the desired result with the least expenditure.

The heading, Excavation 1 on the print, was first driven from both ends of the tunnel. Concurrently with Excavation 1, the arch timbers were placed. The plan was modified to the extent of carrying the bottom of Excavation 1 to 6 feet below the crown block of the arch timbers on the center line, and low enough on the haunches to permit placing the lower wall plates indicated in dotted lines on Plate XI. During the progress of the work it was found that parts of Excavations 2 and 4, sufficient to permit building the side walls, could be made concurrently, and this was done.

Work according to the program outlined was proceeding satisfactorily when by oversight of the yard master, cars too large to pass through the old masonry lining were started through, resulting in collapse of 120 feet of the old lining. At that time there were being offered by connecting lines a large number of cars whose dimensions exceeded

* Chief Engr., Louisville & Nashville Railroad, Louisville, Ky.

Mr. Courtenay.

those permissible through the old tunnel, so, the conclusion was reached to remove the remainder of the old masonry lining and to substitute therefor a timber smoke shield with vertical sidewalls 13 ft. 6 in. apart in the clear, with vertical clearance from top of rail to the knee braces of 16 ft. 6 in.

Steel reinforcement of the concrete was not used throughout the tunnel, but only at points where there were falls of material from the roof.

In 1906 the Louisville & Nashville Railroad Company concluded to enlarge another tunnel about 8 miles south of the above described Covington Tunnel, this last mentioned tunnel being 2147 feet in length and having practically the same section and character of masonry lining as the Covington Tunnel, and having been driven through much the same character of material as the Covington Tunnel. At the time this work was undertaken, double-tracking the line was not in contemplation.

This tunnel was enlarged by removing the old masonry lining in stretches of from 6 to 16 feet, depending upon the general condition of the material behind the old masonry as well as it could be ascertained, and when removing the old lining in short stretches the section was enlarged and new concrete lining of larger section placed.

The procedure was to work on a number of short sections concurrently. No timbering was used for these short sections, and while there were some falls from the roof, none were of any magnitude and there was no serious difficulty.

A few years later it was decided to double-track the line, but the difficulties of again enlarging this tunnel, and at the same time taking care of the traffic, were so great that conclusion was reached to construct the second track in vicinity of the tunnel on a new location some distance away from the old tunnel.

The practice generally of the writer, when having occasion to double-track lines which pass through tunnels, has been to construct an independent tunnel for the second track. This has been accomplished successfully in a number of cases, in some of which the distance between centers of tunnels has been 50 ft., the minimum distance between centers having been 35 feet.

The engineer has frequently to deal with such problems as lining with masonry tunnels which had previously been lined with timber. The practice of the writer with reference to this work has been to line them in short sections about as described above.

At times he also has occasion to deal with bad falls in tunnels. The Cumberland Gap Tunnel, where the States of Kentucky, Virginia and Tennessee corner, is a case in point. This tunnel is driven generally through shale which has a very heavy dip. The tunnel was originally timbered. Some years ago a break occurred in the roof of this tunnel, extending to a height of 80 feet above the track. The situation was a dangerous one for the men engaged upon the work. A heading drift was driven through the debris, the cavity was timbered, and the material

Mr. Courtenay. obstructing the tunnel was removed, the tunnel lined with brick masonry of the horseshoe section, and then the whole of the cavity above the tunnel was packed with rock.

In 1904 the company with which the writer is connected was engaged in constructing a new line of railroad in eastern Tennessee, on which there were a number of tunnels, generally driven through rock. In some of the limestone tunnels large clefts filled with clay were found in driving the tunnels. The procedure, when these soft clay pockets were discovered, was to attempt to hold up the ground at all cost and not to suffer the tunnel to break through to the surface, if it could be avoided. In such ground usually a small drift was driven on the center line at the crown of the tunnel and timbered; then a small drift was driven on each side for the wall plates. When these drifts had extended to 12 feet in length, the timber wall plates were placed and blocked up; then excavation was carefully made from the side drifts to the center crown drift and the timber arch blocks placed; then the remainder of the headings excavated, the tunnels having been driven by the top heading method.

A number of tunnels were driven through clay pockets of the above character and through a formation of yellow clay with a large number of limestone boulders floating therein, under the immediate direction of Mr. J. E. Willoughby, M. Am. Soc. C. E.

A few years after the line through one of these tunnels which had been driven through clay carrying limestone boulders had been put in operation, a rear-end collision occurred between two freight trains in the tunnel. One of the trains was a coal train. The result of the collision was a fire which ignited the coal and also burned out a section of the tunnel which had been lined with timber, the tunnel having been lined with alternate stretches of timber and concrete, the expectation being to complete the concrete lining later.

Material fell from the roof of the tunnel in the burned section until the natural surface was reached, leaving a large hole on the surface approximately conical in shape. The fallen material was wet, for fire engines had been brought to the tunnel and used in an effort to put out the fire.

This problem was attacked by driving a drift of merely sufficient size to let a locomotive through, and timbering this drift with approximately rectangular section of timbering as it was driven; 4-in. by 4-in. oak poling boards 16 feet in length were driven ahead as the work progressed.

Much difficulty was encountered by the men being overcome by fumes from the burning coal as the coal was uncovered, and the work was greatly delayed on this account.

However, the above method was followed, the wrecked engine within the tunnel removed, and traffic restored long before the tunnel could be brought to the adopted section and new concrete lining constructed.

Notwithstanding the fierce fire which roared through this tunnel, the sections which had been lined with concrete were very little damaged.

The concrete had been reinforced with steel rods, and in a number of places the heat caused approximately circular pieces of the concrete about one foot in diameter and from 3 to 4 inches in thickness, to pop out. Where these pieces of concrete were caused to break out from the face of the lining by the heat, it was seen that the concrete reinforcing rods were sharply buckled on account of the expansion due to the heat. Notwithstanding this, the concrete was not seriously damaged and did not require renewal. Mr. Courtenay.

An unusual experience was with a tunnel in southern Alabama. This tunnel had originally been lined with oak timber. When the original oak timber began to show considerable decay, the timber lining was renewed with black cypress, a character of timber which the writer had known to last with very little decay for twenty years in other tunnels. After this cypress had been in place a few years it was discovered to have been almost totally destroyed by dry rot. The timber held its shape, but was so completely decayed that a piece of it 4 in. wide and 2 in. thick and a foot long could readily be broken across between the hands.

The writer's practice has been to require frequent inspections of timber in tunnels by boring, but it was thought the cypress in this particular tunnel had not been in place a sufficient length of time to justify earlier inspection, by boring.

Mr. M. M. O'Shaughnessy,* M. Am. Soc. C. E., wrote that Mr. Churchill's interesting and instructive paper deals exclusively with railroad tunnels, which naturally constitute a very large proportion of the tunnels recently constructed in America, but with the rapid development of the larger American cities tunnels for vehicular, pedestrian and street car traffic are no longer of uncommon occurrence. Mr. O'Shaughnessy.

The first impression that the Eastern visitor obtains on entering San Francisco is surprise at its uneven topography. A dismembered branch of the Coast Range divides the city into two main districts, and spurs from the principal ridge extend in every direction, forming steep barriers between the intervening level stretches. While these hills are a relief from the monotony of outlook so common in Eastern centers of population, and while on their slopes some of the best residences in San Francisco are located, by obstructing vehicle and street car traffic they have, until recently, retarded this city's growth and development. To afford to promising districts beyond the ridges adequate transportation facilities, one tunnel has recently been completed and another is now in course of construction.

STOCKTON STREET TUNNEL

This project was undertaken to connect the North Beach District to the business center by a shorter and more direct route and easier grades.

The entire length is 1323 feet, extending from the north line of

* City Engineer, San Francisco, Calif.

Mr. O'Shaughnessy.

Sutter Street to the south line of Sacramento Street. Of this, 412 feet is in open-cut approaches and 911 feet in tunnel. Approximately 180 feet of the tunnel adjacent to the portals was constructed by the cut-and-cover method. An ascending grade of 2.33 percent begins at the north line of Sutter Street, running thence to the north line of Bush Street, from which point the tunnel rises on a 4.29 percent grade. Fairly hard sandstone was anticipated, but schist, slippery blue shale and yellow clay were penetrated. This failed to arch itself thoroughly in the limited distance to the upper ground surface and during the winter of 1913-14 became saturated, necessitating extreme caution and heavy timbering. The standard tunnel section has a clear span of 50 feet and a rise of 19 feet, affording two 7-foot sidewalks and a 36-foot roadway in which has been constructed a double-track municipal electric railway. As originally designed, the intrados of the reinforced concrete arch was tricentric, the abutments 8 feet thick and the crown 18 inches thick.

Contract for the tunnel construction was awarded in April of 1913, to Jacobsen & Bade for the sum of $337,000, but as it was deemed necessary, owing to the treacherous nature of the strata disclosed in the excavation, to strengthen the section, increasing the crown to 32 inches thickness and the balance of the arch proportionately, the first construction cost was increased to $416,528. Work started on the south approach June 2, 1913, drifts were started in November, 1913; concrete lining completed June 25, 1914; core excavation started July 17 and was completed September 5, 1914.

Open-cut approaches and cut-and-cover sections were done by a 20-ton Marion steam shovel, with a one-yard dipper loading directly into 4- and 5-yard auto trucks. When excavation in the south approach was completed, bunkers for the handling of surplus excavation were constructed at Sutter Street at the end of a trestle along which a train of eight 1¼-cubic-yard side-dump cars, hauled by a 35-hp. electric locomotive, brought material from the three drifts, one of which entered at the crown and one at either side of the core, at sidewalk level. Two upper holes and two lifters 6 feet deep were used in the face of the drift, taking about two hours to drill. The load per hole was usually six sticks of 35% dynamite. When the drifts had been completed, the excavation for the concrete ring was carried out by the crownbar system of timbering.

Crownbars, of which there were twenty along the extrados, had minimum dimensions of 10 inches in diameter and 20 feet in length, were round fir and placed to break joints. Lagging was 3 inches, and posts, round or square, were not less than 10 inches diameter, or on side; transverse sets of timbers were placed on 5-foot centers. Six operations were necessary to complete the excavation between drifts and for the abutments. They were: (1) lowering the floor of the top drift and placing the first crownbars; (2) and (3) widening the top drift and placing additional crownbars; (4) connecting the top and side drifts; (5) excavation of abutments; (6) completing the section ready for the concrete forms.

This excavation was very expensive; about 2,500,000 feet of lumber was used, including forms. Most of the lumber had to remain in the tunnel. Mr. O'Shaughnessy.

After removing the transverse sets of timbers, forms for the concrete were supported by the central core, and 10-foot sections of the reinforced concrete lining, running 18 cubic feet of concrete and 1000 pounds of steel per foot, were poured. The load over the section to be poured was supported by reinforced concrete stulls, 4-in. by 4-in. in section, which rested upon 2-in. by 4-in. wooden blocks on the forms. These stulls were embedded when the concrete was poured, becoming part of the permanent lining. A 1:2:5 mix of Santa Cruz Portland cement, sand and rock was used. Near the south portal, concrete materials were brought into bunkers and flowed by gravity through chutes into a 1-yard Foote mixer operated by a 15-hp. electric motor. Concrete was dropped from the mixer into a steel tank, whence it was forced by compressed air into the forms. The compressed-air plant which supplied air to drills, for ventilation and for delivering concrete, was situated over the tunnel, and consisted of an Ingersoll-Rand, 16 by 18 two-stage compressor driven by a 200-hp. motor. A 4-inch air inlet and an 8-inch discharge pipe were fitted to the concrete drum. The output of the mixer, 160 cubic yards in 8 hours, was easily handled, a cubic yard of concrete being moved in 2 minutes. Concrete was transported a maximum distance of 1000 feet, in which distance it was elevated 90 feet; a pressure of 125 pounds per square inch was used. Labor costs were high in shifting the 8-inch discharge pipe, and the L's and other specials had to be renewed often, the life being about 60 hours' actual use, or 1200 cubic yards concrete transported. Straight pipe wore at couplings and had to be recut and rethreaded.

After the concrete arch had thoroughly set, a 15-ton Marion steam shovel of the revolving type with a ⅝-cubic-yard dipper was used in removing the core. The surface of the concrete was thoroughly cleaned and roughened, and the 2-in. by 4-in. wooden blocks which supported the stulls were removed, the resulting pockets being filled with a rich mixture of cement and gravel. A scratch coat of 1:2 cement plaster was then applied, over which was placed a finish coat of Medusa plaster.

Cast iron drainage pipes 4 inches in diameter extend through the abutments every 25 feet on either side of the tunnel for its full length, and lead into 6-inch ironstone pipe drains under the sidewalks, where they are connected to the main sewer in lower Stockton Street. An underdrain along the center line of the tunnel conveys seepage from the roadbed of the railway to the main sewer.

There are 23 expansion and settlement joints of copper and tar paper placed at regular intervals.

To light the tunnel electric conduits were embedded in the concrete with globe connections at 25-foot centers.

The cost, $616,528, was met by a graduated scale of assessments paid in ten annual installments on the property benefited on both ends of the tunnel; $416,528 was the cost of construction and the balance paid for damages to adjacent lands.

Mr. O'Shaughnessy.

COST SUMMARY.

	Labor	Material	Unit	
Excavation				
Open cut	1.47	0.21	cu. yd.	Labor includes 66c for hauling, sub-contract.
Headings	6.25	1.60	cu. yd.	Includes timbering
Stopes	6.50	2.12	cu. yd.	
Core	1.24	0.20	cu. yd.	
Steel				
Open-cut sections	8.69	28.42	1000 lb.	
Tunnel	14.76	28.58	1000 lb.	
Concrete				
Plastering	0.47	0.51	sq. yd.	
Open-cut section	0.84	5.39	cu. yd.	
Tunnel section	0.82	5.79	cu. yd.	
Forms				
Tunnel	41.17	2.06	100 sq. ft.	
Open-cut section	2.98	0.37	100 sq. ft.	

TWIN PEAKS TUNNEL

This project is now in the course of construction. The bore commences at 17th and Castro Streets, and extends in a general southwesterly direction, penetrating the Twin Peaks Ridge 925 feet below the highest peak and terminating in a 10,000-acre tract of land highly desirable for residential purposes. The tunnel will provide much needed rapid transit facilities to the entire district beyond the ridge. Funds to the amount of $4,000,000 for construction and for the acquisition of the necessary lands were raised by means of a graduated assessment plan. One eighth of this sum was required for the purchase of necessary lands and rights of way, including a strip 1900 feet long and 90 feet wide from the present southwesterly terminus of Market Street.

Commencing at the easterly end, the 12,000 feet of length is divided as follows:

East approach, 187 feet; east portal and subway section, 292 feet; Eureka Valley Station, 300 feet; subway section, ventilating intake station, 18th and Hattie Streets, 1072 feet; 29 ft. 6 in. tunnel section, 30 feet; taper connection, 180 feet; standard tunnel section 5144 feet; ventilating intake, Relief Home Tract; standard tunnel section, 1347 feet; Laguna Honda Station, 300 by 44 feet; standard tunnel section, 2988 feet; west portal and west approach, 85 feet. A 3% ascending grade obtains from Market and 17th Streets, elevation 139 feet, to the Laguna Honda Station, elevation 375 feet, and thence a 1.15% grade descends to the west portal, elevation 340 feet. The west portal, which leaves Market Street near 17th Street, is designed to connect with a future subway in Market Street.

The subway section was adopted for the entrance because of the limited overhead clearance. It has two compartments, each 14 ft. by 15 ft. in the clear, and runs 8 cubic yards of concrete and 900 pounds of reinforcing steel per foot.

Eureka Valley Station has platforms 300 feet long to accommodate each track, and stairways at each corner connecting with kiosks at the upper street level. This station is designed to accommodate trains from a future Mission-Sunset tunnel to the southeast corner of Golden Gate Park. Mr. O'Shaughnessy.

Work is practically completed up to 18th Street, over which distance fee simple title has been acquired to a 90-foot right of way, the surface of which is to be used for vehicles and street traffic as a portion of the Market Street extension, part of the plan to construct a scenic boulevard on easy grades around the Twin Peaks Ridge.

For all of the west approach, subway section and Eureka Valley Station, excavation was done in open cut through yellow and red sandy clay with a Marion steam shovel, 1½-yard dipper loading directly into 4- and 5-yard motor trucks. The surplus material was hauled an average distance of 3 miles to the Islais Creek District where it was used in deep fills to bring Oakdale and San Bruno Avenues, links in the system of boulevards, to grade. The cost of removing and hauling was about $1 per yard—35c for labor, 65c for hauling. The cut on the subway section varied from 25 to 40 feet and the sides stood on a 1 to 4 slope, little water being encountered. Piles were driven to hold the embankment from Ord Street to 10 feet west of the taper connection. Over this stretch a Vulcan steam shovel with a 1¼-yard dipper worked on an upper bench, the Marion shovel following on the sub-grade level. Concrete work followed the excavation and inclines were constructed at intervals to permit the motor trucks gaining the intersecting street levels.

At 18th and Hattie Streets is located one of the two ventilating stations, each of which has a capacity of 75,000 cubic feet of air per minute, at a pressure of 0.7 ounces. A complete change of air will occur throughout the tunnel every 20 minutes. The ceiling slab in the standard tunnel section has openings every 100 feet, which are made adjustable to suit the air pressure at that point. By this means it is hoped to avert the defective attempts at tunnel ventilation heretofore employed, as foul air will be removed from all portions of the tunnel by simultaneous drafts. The area of the 5-ft. by 15-ft. segmental air chamber between the ceiling slab and the intrados of the arch is 64 square feet.

The subway cut crosses 18th Street, and the piles which were driven on the lines of the cut at 4-foot centers were capped and 12-in. by 16-in. stringers spread solid to form a bridge to carry the 18th Street car line. Along about this point the steam shovels gave way to hand loading into auto trucks. To minimize the hand labor, a 10-foot core remains, the footings to be poured in side trenches up to the bottom level of the tile drain, which will be set before the side walls, ceiling slab and arch are poured. A shovel operated by compressed air piped from Laguna Honda Station—where is situated a plant of three compressors of 3000 cubic feet capacity, each operated by a 200-hp. motor—will later remove this core and load into cars, on tracks, which will be drawn into the finished subway section and up an incline motor-driven, endless-chain escalator

Mr. O'Shaughnessy. through openings 10 by 30 feet left in the roof slab of each compartment at Ord Street. The surplus will be used for backfill over the subway section.

Concrete for approach walls, open-cut section and Eureka Valley Station has been completed. The mix for the entire project is 1:2¼:5, with 8 pounds of hydrated lime to 100 pounds of cement. Santa Cruz Portland cement, 1 part river sand to 2 parts bank sand, Niles gravel and Pyramid brand hydrated lime are being used.

TWIN PEAKS TUNNEL QUANTITIES

Concrete	78,000 cu.yds.
Excavation	480,000 cu. yds.
Rock	70,900 cu. yds.
Cement	95,900 bbls.
Sand	31,900 cu. yds.
Steel	2,612 tons.
Hydrated lime	1,534.4 tons.

Of the total cost of the project 85% was raised by 10 annual installments from the undeveloped land on the southwest terminal which will be brought within 8 minutes of the settled portion of the city; and the remaining 15% from the property on that portion of Market Street on the northeast end adjacent to the work. The entire time of construction is estimated at 3 years, when a rapid transit line will be operated through the tunnel.

Mr. Churchill. **Mr. Chas. S. Churchill**, in closing, and referring specifically to the Rogers Pass tunnel, said that the continued rapid progress on this construction during the year 1915 bears out all the statements made commendatory of the special method adopted by Mr. J. G. Sullivan, Chief Engineer, in this construction.

Mr. W. H. Courtenay, in his further description of the enlargement of Covington tunnel, shows the difficulties that have been met with in various works of this character, many of which have been undertaken by railroads in the East that pass through the Blue Ridge and Alleghany mountain systems, where variations in character of material are extreme and frequent geological faults are encountered. He also brings out clearly the fact that it is good practice, and which is in general use, to build a second single-track tunnel instead of enlarging an old single-track tunnel under traffic conditions; and he finally describes many of the difficulties that have arisen in connection with the maintenance of railroad tunnels through these mountain systems.

Mr. M. M. O'Shaughnessy has added a detailed description of some highway tunnel work in San Francisco. These cases are properly listed under the general head of "Tunnels" (the title of the paper), because, as a matter of fact, there are no material differences met with in the construction of a highway tunnel from what are experienced in building a double-track railroad tunnel; and any conclusions that may be drawn

Mr. Churchill.

from the one are just as applicable to the other. Even in the matter of ventilation, the writer now wishes to record the fact that he has constructed, and has under way, the ventilation systems for operating purposes of steam railroad tunnels, electrically operated tunnels, and highway tunnels where automobile traffic is heavy. So, similarity exists in both construction and maintenance.

In conclusion, the writer desires once again to call particular attention to the tabulated statement, from a study of which it will be noted that any method of tunnel excavation by which speed is secured primarily by use of explosives results in an excess of excavation and some lack in economy; and those methods described which in the case of double-track tunnels produced rapid progress with the moderate use of explosives and with small amount of excess excavation per foot of tunnel, are those that call for special study in future tunnel construction of all kinds.

Paper No. 84

TUNNELS RECENTLY CONSTRUCTED IN ITALY.

By

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GENERAL INFORMATION.

Italian railways are characterized by a large number of tunnels. Many of these tunnels are very important, on account of their great length, and others for the difficulties of construction or the rapidity with which the headings were driven.

The tunnels famous for their great length are naturally few, but among the most important—from 5 to 11 miles long—may be mentioned the Mont Cenis tunnel, 13,671 metres (44,785 feet) long, and the Simplon tunnel, 19,803 metres (64,536 feet) in length, the longest of all; both of these tunnels are very well known.

Then comes a group of three tunnels: Capo Sele, 15,256 metres (50,052 feet); Croce del Monaco-Ginestra, 15,833 metres (51,945 feet); and Murgie, 16,071 metres (52,726 feet) long. Among the new tunnels now in course of construction are those of Isoverde, on the new direct line between Genoa and Milan, 19,450 metres (63,812 feet) long, and Montepiano, on the Florence- Bologna line, 18,650 metres (61,187 feet) long. They form a group of very important examples of good tunneling.

The number of tunnels from 1 to 5 miles in length is, of course, larger; and among them, and deserving of special mention, is the Ronco tunnel (on the Genoa-Milan line), 8,306 metres

(27,251 feet) long, which gave much trouble during construction owing to the bad character of the blue marl-rock encountered. This material, in contact with damp, hot air, swelled up and caused such great pressure that ordinary revetments were crushed, and in some places granite revetments 10 feet thick had to be adopted.

The tunnels less than one mile in length are almost countless. Then there are lines where the length of tunnels is almost equal to that of the line in the open. For instance, on the Genoa-Spezia line, 92 kilometres (57.3 miles) long, there are 114 tunnels, several over three miles in length, and all together measuring about 45 kilometres (28 miles), or half the length of the line.

On the new direct Rome-Naples line, now nearing completion, the section between Terracina and Formia—about 50 kilometres (31 miles)—has a total length of tunnels of 27 kilometres (17 miles), or more than half the length of the line. Three of these tunnels are each nearly 5 miles long.

In fact, Italy might be called the "Country of Tunnels".

Owing to its hilly conformation, there are tunnels everywhere and for all purposes; that is, not only for railways, but also for ordinary roads, some of which date from the time of the Romans, as the "Passo del Furlo"; tunnels for drainage purposes, dating even as far back as the Etruscan period, about 600 years B. C.—and of these there are tens of thousands of miles in Central Italy, especially around Rome: and tunnels for carrying water, either for aqueducts or water-power, among which, deserving of a passing note, are the Albano Lake tunnel near Rome, 1,200 metres (3,940 feet) long, excavated through tufa rock in 18 months by the Romans, 397 B. C.; and the Fucino Lake emissary, 4,800 metres (15,748 feet) long, driven during the reign of the Emperor Claudius, between 41-52 A. D., which is really a monument to the engineering skill of the Romans.

Among modern aqueducts may be mentioned the "Pugliese", 1175 miles long, perhaps the largest in the world: for a length of 213 kilometres (133 miles) of main line, it is of ovoidal section of 8 by 9 feet (see Fig. 6), with 97 tunnels, measuring 93 kilometres (58 miles) in all, or 44% of the total. Three of these tunnels are each over 9 miles in length. They have just been completed and will be described later on, as they constitute some

extremely important works and are notable for the exceptional rapidity with which their headings were driven.

In passing in review some of the most interesting tunnels recently built in Italy, and not yet well known, we may classify them in the following order:

1. Railway tunnels of great length, or which have presented special difficulties.

2. Aqueduct tunnels of small sections but of very great length.

3. Tunnels of very wide section, more than 50 feet in width, for ordinary road traffic.

1. RAILWAY TUNNELS OF SPECIAL LENGTH OR DIFFICULT CONSTRUCTION.

(a) Tunnel of Montorso on the New Direct Rome-Naples Line.

It is 7530 metres (24,700 feet) long, with the section represented in Fig. 1, which is the usual section on important lines.

The rock is fissured limestone, with some caverns: one of these caverns extends about 35 feet below and above the line and is 70 feet long. It was filled with packed stone up to the plan of formation, and was then covered with an arch, with very strong piers, which were used also to support the roof of the cavern.

The headings were driven from the two portals, without any intermediate shaft; compressed-air Ingersoll rock-drills and dynamite were employed, with the following results:

Rome heading	
Average daily advance	8 ft.
Maximum daily advance	14 ft.
Naples heading	
Average daily advance	9 ft. 2 in.
Maximum daily advance	15 ft. 6 in.

Some sections, at the beginning of the work, were also driven by hand drills, with an average advance of 6 ft. 6 in. and a maximum of 10 feet per day at each heading, which is most notable and forms almost a record.

Owing to the solid nature of the rock, the revetment is from 16 to 22 inches thick, made of ashlar masonry with courses of bricks in the crown and of dressed stones in the haunches. The tunnel was begun in June, 1907, and finished in March, 1911.

(b) Tunnel of Vivola on the New Rome-Naples Line.

This tunnel is 7454 metres (24,455 feet) long, with cross section as in Fig. 1.

For about 450 metres (1480 feet) on the Rome side, the ground was of loose clay with big boulders; the remainder, good limestone with much water.

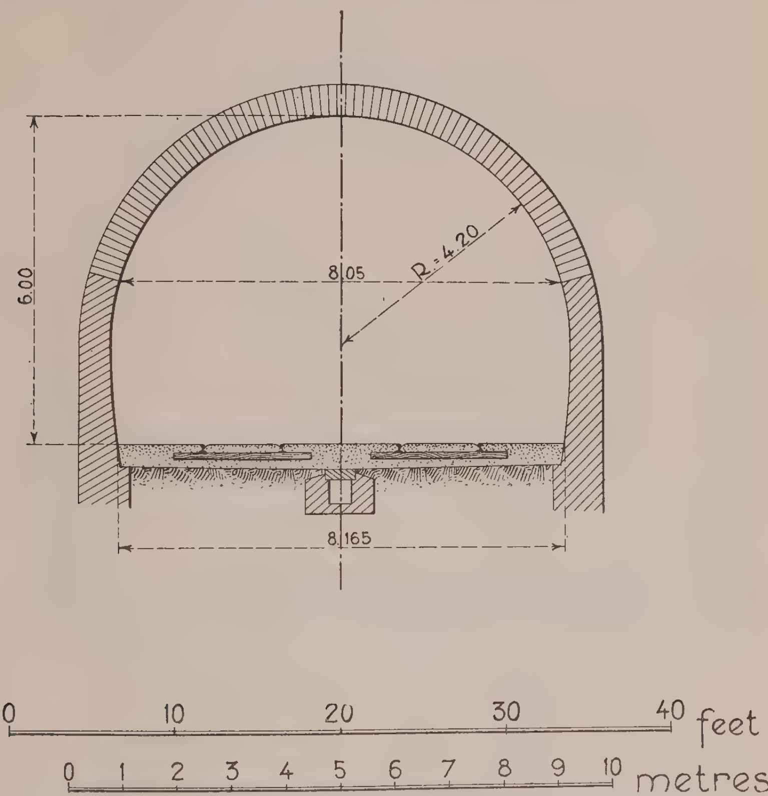


Fig. 1. Tunnel on the New Rome-Naples Line, Through Good Limestone Rock.

The headings were driven at formation level, by hand through the clay and by compressed-air rock drills in rock. The explosive used was dynamite. Electricity was used throughout for driving the air compressors and locomotives and for lighting the tunnel and yards. This helped materially in attaining the noteworthy rapidity with which the headings were driven.

Rome heading
- Average daily advance........................ 8 ft. 3 in.
- Maximum daily advance........................ 16 ft. 8 in.

Naples heading
- Average daily advance........................ 12 ft. 9 in.
- Maximum daily advance........................ 27 ft.

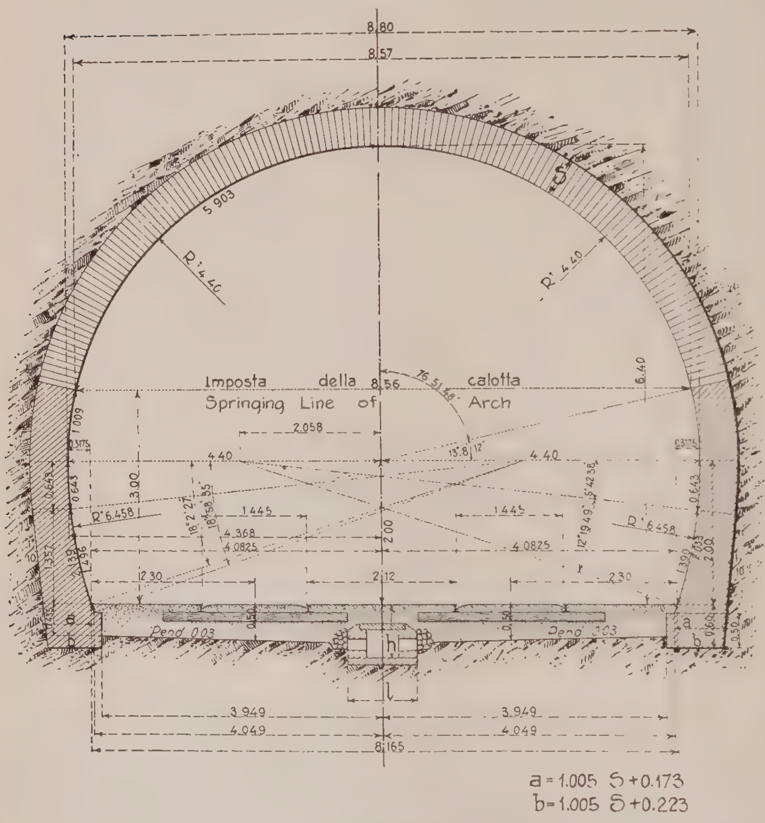


Fig. 2. Massico Tunnel, New Rome-Naples Line, Through Very Fissured Limestone Rock with Deep Caverns.

In the short section excavated by hand through boulder clay the average daily advance at each heading was 5 ft. 10 in.; the maximum, 10 ft. 4 in.

Except in this section—where the revetment was made of bricks and dressed stone, 30 inches thick—all the tunnel was lined with ashlar masonry only 16 inches thick.

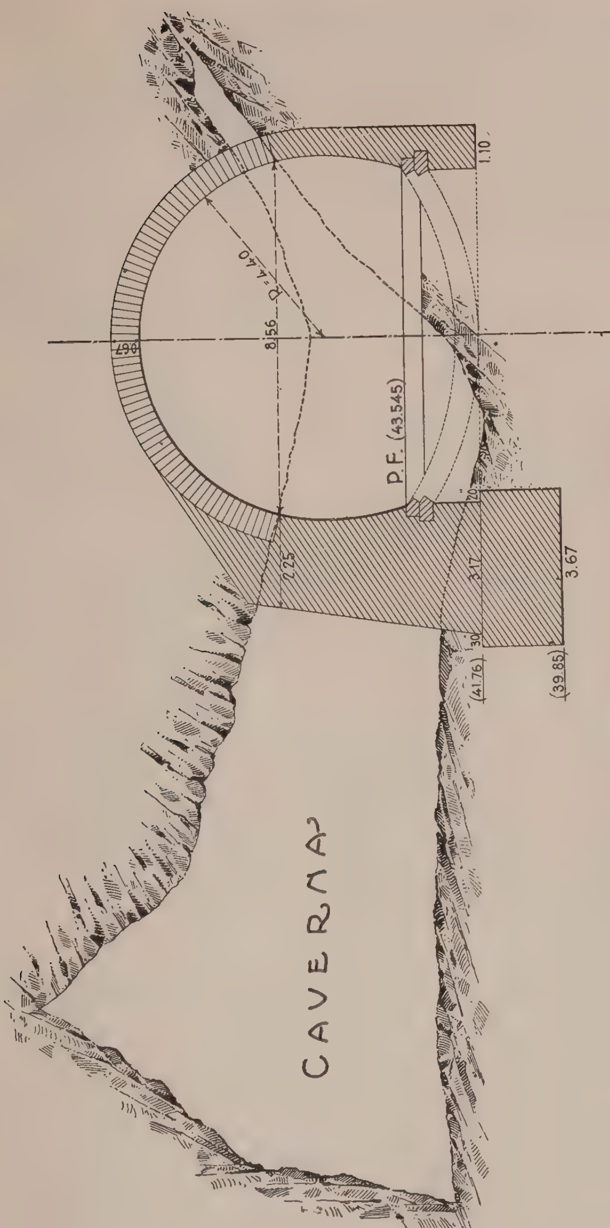


Fig. 3. Massico Tunnel Through a Cavern.

The tunnel was begun at the end of October, 1909, and was finished at the beginning of November, 1912.

(c) Tunnel of Massico on the New Rome-Naples Line.

The total length is 5365 metres (17,601 feet), with section as Fig. 2.

For the first 425 metres (1390 feet) the mountain is formed of volcanic sand and fragments of lava; the rest is limestone, very minutely fractured and, in places, mixed with clay, with abundant springs. Also chaotic deposits of big blocks were met with, evidently due to large caverns that have caved in, as three caverns of some 60 by 90 feet were still open and happened to be across the tunnel (Figs. 3 and 4).

The headings were driven at crown level when in loose volcanic sand, and at formation level where rock was met with.

In loose material, the excavation was done by pick and shovel, heavy timbering being necessary; thus, the advance was only from 5 to 6 feet daily.

In rock, Ingersoll rock-drills and Demag air-hammers were employed, together with either dynamite or Nobel gelatine, Nos. O and 1.

Rome heading	
Average daily advance	12 ft. 6 in.
Maximum daily advance	22 ft. 8 in.
Naples heading	
Average daily advance	12 ft. 7 in.
Maximum daily advance	23 ft. 6 in.

On the Naples side, in a good section of limestone rock, a daily advance of 21 ft. 10 in. was maintained for some weeks in succession.

The revetment for the sides was made of ashlar masonry; the arch was partly of bricks laid in cement mortar and partly of Portland cement concrete.

The section through the caverns had to be carried on with greater precautions, owing to the loose nature of the rock, which, when disturbed, would fall in great blocks. The roof of the cavern also had to be supported on strong masonry piers (Figs. 3 and 4), so that the work begun in September, 1911, was not finished till April, 1915, notwithstanding the rapid advance made in the good sections of rock formation.

(d) Tunnel of Borlasca on the New Genoa-Ronco-Arquata Line.

The tunnel is 4042 metres (13,260 feet) long, 8.80 metres (29 feet) wide at the springing of the arch, 4.40 metres (14 ft. 6 in.) radius, and 6.40 metres (21 feet) high.

The geological formation consists of limestone for one fourth of the length, and for the rest of conglomerate varying from very

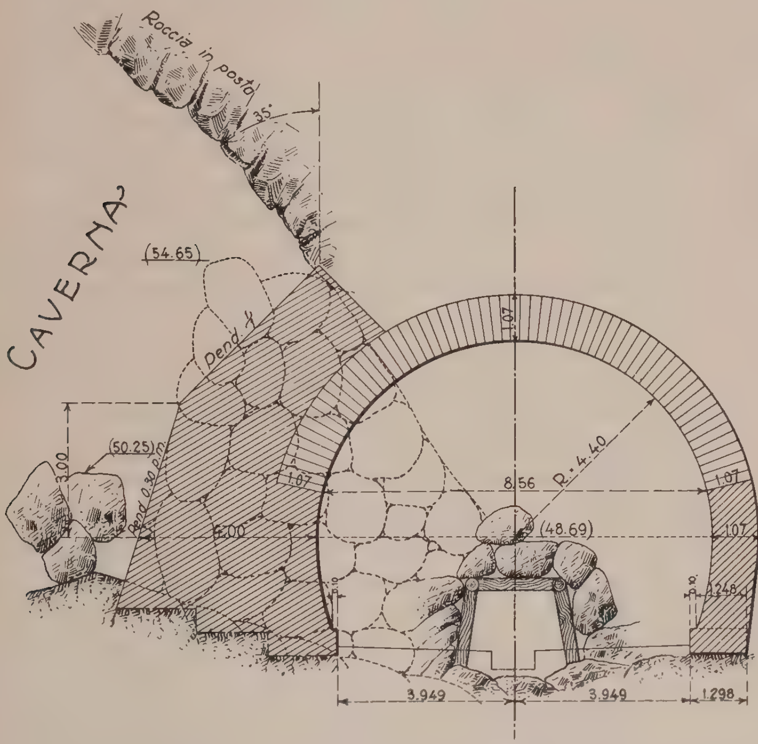


Fig. 4. Massico Tunnel; Through Loose Debris Fallen From Roof of a Cavern.

fine sandstone to big pebble pudding cemented by lime and clay. Some fractures were met with that gave a good deal of trouble on account of the large quantity of water mixed with sand and mud that sometimes flooded the tunnel.

Except for small sections driven by hand at the two entrances, and in some parts where fractures occurred, the headings first and then the rest of the tunnel were excavated by com-

pressed-air drills, either of Ingersoll or Demag type, aided by air-hammers for the widening of the headings.

The revetment is made in some parts with brick masonry 22 inches thick, in other parts with Portland-cement concrete 20 inches thick, made in the proportion of 300 kilos of cement, 0.5 cubic metre of sand and 0.8 cubic metre of small gravel, or nearly in the proportion, by volume, of 1-1/4 : 2-1/2 : 4.

Where the ground is bad, the revetment reaches in some places a thickness of 3 feet.

The tunnel was begun in February, 1913, and the average monthly advance of the headings has been about 120 metres, corresponding to about 13 feet average per day. It is expected that the work will be finished in the autumn of 1915.

(e) Gattico Tunnel on the Borgomanero-Arona-Simplon Line.

This tunnel is not famous for its length—it is only 3308 metres (10,853 feet) long—but for the exceptional difficulty in construction, which required the use of compressed-air caissons sunk from above.

For about two-thirds of its length the tunnel passes through very bad glacial mud and debris, extremely rich in water.

This formation is about 200 feet thick above the crown of the tunnel, so it was out of question to make an open cutting, and a tunnel could not be avoided, although great difficulties were foreseen.

Owing to the nature of the ground, the work had to be done by pick and shovel, with heavy timbering; and from the very inception of the work very powerful pumping engines were used in order to get rid of the water. The work was thus pushed with great care and expenditure, but when under an old glacial drift, and for a section of about 190 metres (625 feet), all the usual remedies which were resorted to—including very important drainage wells, sunk laterally to the tunnel by compressed air—failed to get rid of the enormous amount of water that filled the headings. These difficulties, aggravated by sudden inrushes of mud and debris, and even enormous glacial boulders of very hard quartzite, demonstrated that other and radical methods were indispensable in order to finish this section of the tunnel. At the time the work was in progress, that is, in 1897, the method of shield tunneling, since developed with the aid of compressed air, was not very reliable.

So it was decided to attack this section not from the headings but from the top, taking advantage of the fact that the surface of the ground was only about 200 feet above the crown of the tunnel.

For this purpose a heavily-timbered vertical trench 35 metres (115 feet) deep was dug from the surface down to about 25 metres (80 feet) above the crown of the tunnel, and down to this depth the inrush of water was tolerable.

Then at the bottom of the trench a file of eleven caissons, 27.30 metres (90 feet) long and 6.80 metres (22 ft. 6 in.) wide, was laid ends on, the width of the caissons being slightly greater than the outside width of the revetment of the tunnel.

The caissons were sunk one by one till the top of the working chamber was lower than the bottom of the tunnel. In the meantime, over the working chamber a section of the revetment of the tunnel was built, which also by its weight helped in sinking the caisson. The normal working pressure of the air was 1 1/2 atmospheres. When two adjacent caissons were put in place, the ironplates of the two iron diaphragms, between the two sections of the tunnel, were taken away one by one on each side—and, of course, still working in compressed air. Then the revetment was carried on by working horizontally, doing very small portions of excavation and proceeding immediately to their revetment, which was done with bricks and cement mortar, often reinforced with strong iron beams passing from one caisson to the other across the gap to be filled. It was a most difficult work, but was carried out without mishaps and without any loss of human life. This section was made by means of 11 caissons, the total measurement being 186 metres (593 feet). The cost per metre run was 5800 francs or $345 per linear foot.

The whole tunnel, 3308 metres (10,853 feet) long, was completed in 3 years and 9 months, which is almost a record, considering that the similar tunnels under the Mersey at Liverpool and under the Thames at Blackwall (London)—one half and one quarter as long, respectively—required 4 and 5 years of assiduous work.

The Directors of the works were Com. Oliva and Com. Cauda of the Mediterranean Railway Co.

2. TUNNELS OF SMALL SECTION AND GREAT LENGTH FOR AQUEDUCTS.

Tunnels of small section for water-power installations or for aqueducts have been built in very large numbers during the last decade, and among the most notable those of the Pugliese Aqueduct are most important. In passing, it may be mentioned that this aqueduct—of which two-thirds of the most difficult sections are already completed—is 1890 kilometres (1175 miles) long, without counting the network of distributing pipes to the 536 towns, making it one of the most important in the world.*

It is made to convey 6 cubic metres (1585 gallons) of water per second for a length of 213 kilometres (132 miles), from Capo Sele to Villa Castelli in Apulia, South Italy. Then it divides into two main branches; one branch of 1.5 cubic metres (400 gallons) capacity, 46 kilometres (28.6 miles) long, going to Foggia; and another branch of decreasing section, 1600 kilometres (995 miles) long, to Bari, Lecce, Taranto, up to the extreme point of Italy at Santa Maria di Leuca.

As already mentioned, in the main section from Capo Sele to Villa Castelli there are 97 tunnels, measuring, in all, 93 kilometres (58 miles). Three of them are over 15 kilometres (9 miles) long, and all present very interesting features.

(f) Capo Sele Tunnel of Pugliese Aqueduct.

This tunnel is 15,252 metres (50,038 feet) long, and in ordinary ground is oval in shape—2.70 by 2.90 metres (8 ft. 10 in. by 9 ft. 6 in.) with a cross section of 6 square metres (65 sq. ft.) and a revetment 0.40 metres (16 inches) thick (Fig. 5). In bad ground the section is quite circular (Fig. 6), with an internal diameter of 2.85 metres (9 ft. 4 in.), and the revetment is 0.8 metre (2 ft. 8 in.) thick in order to resist the external pressure.

The revetment is generally made of bricks laid with cement mortar, or of Portland-cement concrete in the proportion of 1:2:4.

The geological formation was of fairly good limestone for about 400 metres (1300 feet) from the north portal, then pliocenic blue clay with boulders for 6152 metres (20,180 feet)

* The Catskill aqueduct for New York City water supply is only 143 kilometres (89 miles) in length, but it conveys nearly 5 times as much water.

from the south portal; the rest, 8700 metres (28,540 feet), was *argille scagliose* or "eocenic slate blue-clay", in some parts quite crushed and plastic, owing to infiltration of water, and forming the worst ground that can be met with in Italy. In fact, Italian engineers entertain for these *argille scagliose*—which unfortunately are not rare—the greatest aversion, as the accidents to the famous tunnels of Cristina and Starza, on the Naples-Foggia

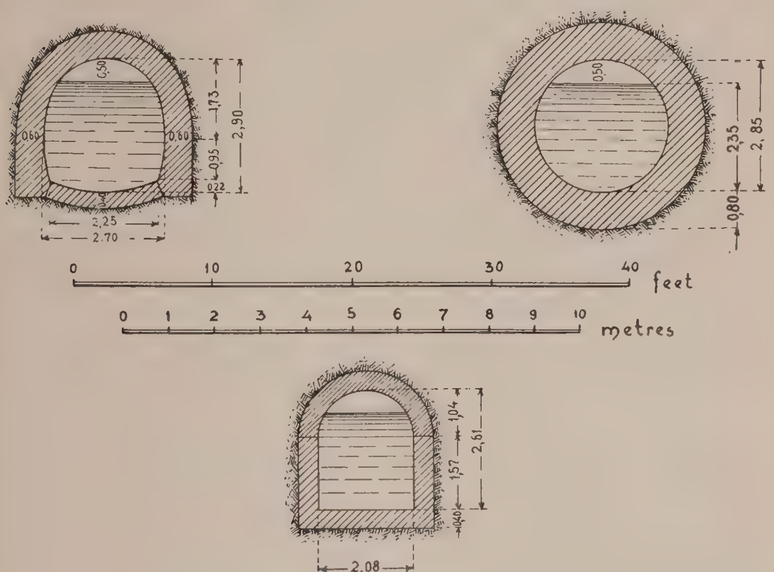


Fig. 5 (top, left). Capo Sele Tunnel, Pugliese Aqueduct. Section Through Slaty Blue Clay, Rather Bad.
Fig. 6 (top, right). Capo Sele Tunnel. Section Through Fissured Slaty Clay, Very Bad and Watery.
Fig. 7 (lower, center). Murgie Tunnel, Pugliese Aqueduct. Section Through Good Limestone.

line, are not forgotten. These tunnels had to be rebuilt three times—with revetments 10 feet thick, although for single line—before they stood the outside pressure.

Italian experience on this subject now proves that the work must be pushed on with the greatest speed, with most ample ventilation of the heading, and with absolute absence of steam or gasoline locomotives that may generate heat or produce warm

damp air, which is the cause of the rapid disintegration and expansion of these *argille scagliose.* Then, of course, the masonry revetment must be made as soon as possible—and in short sections—in order to leave the rock exposed to the air for the shortest possible time and, in any case, for only a few days.

For these reasons, electricity only was used in this tunnel, both for lighting and for motive power, including locomotives; and compressed-air rock-drills, coupled with strong ventilation at the headings and active aspiration of the vitiated and damp air at the portals, kept the inside of the tunnel, not yet lined, as cool and dry as was possible under the circumstances.

The average daily advance at each of the four headings was 8 metres (26 ft. 6 in.) in rock; 6 metres (20 feet) in good, strong blue clay not hydrated; and 3 metres (10 feet) in *argille scagliose,* or slaty clay, which necessitated heavy timbering and special precaution for rapid lining with masonry, so as not to give the ground time to swell up under the influence of the damp, warm air of the tunnel.

Notwithstanding all this care and precaution, many sections of the tunnel caused great anxiety on account of the infiltration of water and, especially, on account of the inflammable gases (*grisou*) met in some places and, also, by reason of a large pocket of mud found in an old buried valley, which could not be crossed and had to be avoided by going around it.

The tunnel required nearly five years of work, and considering its exceptional length and that it could be attacked only from the two portals and one intermediate shaft, the progress attained is really quite notable.

(g) Croce del Monaco-Ginestra Tunnel.

The length is 15,823 metres (51,912 feet), with nearly the same cross section as shown in Fig. 5.

The geological formation was of volcanic sand and tufa for about 1 kilometre from the portals, while the central part was of pliocenic blue clay alternated with strata of miocenic sandstone and marl.

Only hand excavation was possible in such ground, and all the precautions for clayey stuff had to be adopted, both for ventilation and electric haulage of materials.

However, the great difficulties met with in this tunnel were

the bad nature of the ground, the combustible gases (*grisou*) and abundant springs, aggravated by sudden inrushes of quicksand or mud.

But the worst of all was a section 102 metres long (about 340 feet) where sulphuretted hydrogen poured into the heading and caused the workmen to faint or even to fall asphyxiated. So, exceptionally strong ventilation and special protections for the men had to be adopted, such as helmets for working in deadly gases before this very dangerous section could be bored and lined. Now it does not give any further trouble.

The work was carried on from the two portals and from three intermediate shafts; but owing to the great difficulties met with, it required nearly six years to finish it, which is also a very good result.

(h) Murgie Tunnel.

This is the longest tunnel of all—16,021 metres (52,726 feet) —and its cross section is 4.85 square metres (52 square feet), as it has to carry only 5 cubic metres (1320 gallons) of water per second.

Its section (Fig. 7) is rectangular, 2.08 metres (6 ft. 10 in.) wide by 2. 61 metres (8 ft. 6 in.) high, including the semi-circular arch.

The revetment, 0.40 metres (16 inches) thick, is made entirely of Portland-cement concrete, in the proportion of 300 kg. cement, 0.5 cubic metre of sand from crushed rock, and 0.8 cubic metre of 1-inch crushed limestone—or 1¼ : 2½ : 4 parts by volume. The interior is laid with 1 :1 cement mortar trowelled very smooth.

The tunnel is cut through a uniform limestone formation of the cretaceous period, not very hard and fractured in many parts. Also small caverns were met with. The almost complete absence of infiltrations was most notable and, in fact, the water for the concrete had to be brought by auto-cars.

The excavation has been done, by means of compressed-air hammers, from the two portals and from five shafts 12 feet in diameter and 32 to 192 metres (105 to 630 feet) deep, provided with electric elevators of 3 tons power.

The average advance at each heading was 4 metres (13 feet) per day, but in some sections an advance of nearly 9 metres (30

feet) per day was attained for several weeks. This was due to the excellent nature of the rock, which, besides being easily excavated, did not require any timbering and stood perfectly for many months—that is, until the revetment could be completed—which gave great freedom in carrying on the work. Nothing special, and only one very deep cavern, was met. This cavern might have threatened the stability of the tunnel with falling debris, so the tunnel was deviated for about 300 feet in order to pass outside the sides of the cavern into the solid rock.

The motive power for the locomotives was electricity.

The work was finished in 26 months, and considering the exceptional length of the tunnel and that the region was without roads (a service line 2-feet gauge and 20 kilometres long had to be built), without water, and without dwellings, and that workmen, food and water had to be brought from afar, the rapidity of construction was quite exceptional.

These three tunnels were carried out under the direction of Signori Bazzocchi and Maglietta.

3. TUNNELS OF VERY WIDE SECTION, FOR ORDINARY ROADS.

Two tunnels notable for their exceptional width of 50 feet—and one of them for the great difficulties of construction—were built during the last decade, one through the hill of Faro in Genoa and the other through the Quirinal Hill in Rome, right under the Royal Palace.

(i) Faro Tunnel in Genoa.

The harbour of Genoa, the most important of Italy, is separated from its industrial suburb of Sampierdarena by a rocky hill. The only communication by carriage road, until a few years ago, passed at a height of about 20.50 metres (68 feet) above the sea, while a level road between the harbour and the industrial center was sadly needed.

Thus, in 1907 a tunnel was decided upon, the plans of the late Signor O. Bernardini adopted, and the work carried out by Cav. L. Biondi.

The tunnel (Figs. 8 and 9) is 961 ft. 3 in. (293 metres) long, 49 ft. 2 in. (15 metres) wide and 26 ft. 3 in. (8 metres) high at the crown, with a gradient of only 3 feet on the whole length.

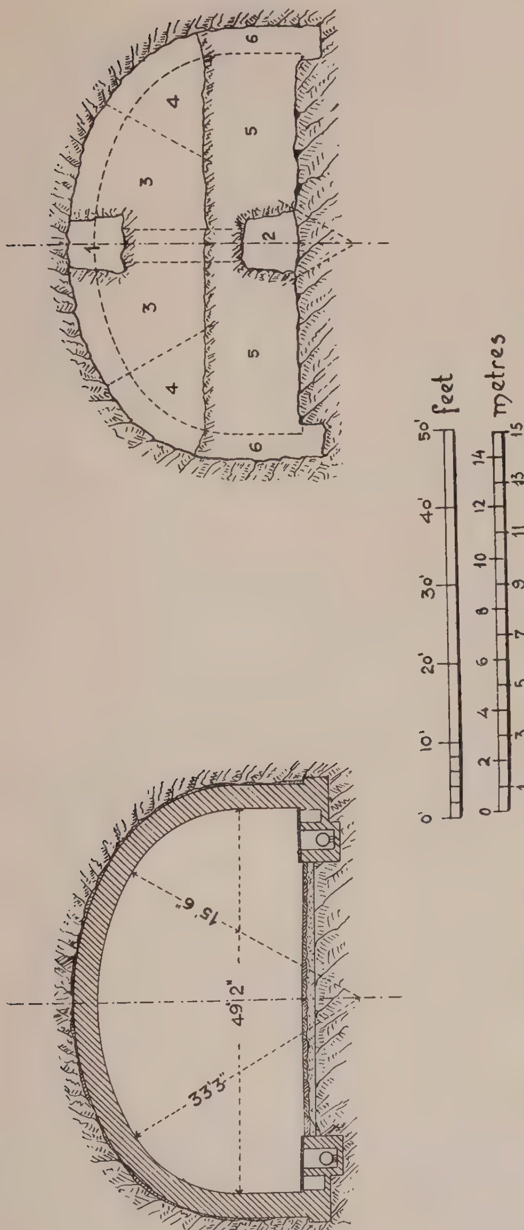


Fig. 8 (left). Faro Tunnel Near Genoa, for Ordinary Traffic. Section Through Good Limestone Rock, with Light Revetment.
Fig. 9 (right). Faro Tunnel Near Genoa. Diagram of the Successive Stages of Perforation and Revetment.

It is excavated through the limestone rock forming the hill of "Faro" by means of small headings, as shown in Fig. 8, where the numbers indicate the successive phases of the excavation. The masonry of the arch was built between the fourth and fifth phases, whilst that of the side walls was built only after the entire excavation had been completed.

The quantity of material excavated was 53,470 cubic yards, and cost an average price of about 3 dollars per cubic yard.

The blasting holes were drilled by hand and the explosive was dynamite. No difficulties of any sort were encountered.

The arch is of bricks laid in cement mortar; the thickness varies from 2 ft. 7½ in. to 4 ft. 7 in., according to the nature of the rock.

The side walls are of rubble stone with a facing of ashlar masonry. The two entrances are of architectural design.

The cost was as follows:

Excavation	$159,133
Inside masonry and pavements	81,878
Entrance portals	32,046
Total	$273,357

(j) Quirinal Tunnel in Rome.

This tunnel connects the lower districts of Rome with the Central Station and serves a very intense traffic of tramways and ordinary vehicles.

It is 350 metres (1150 feet) long, 15 metres (50 feet) wide, 9.50 metres (31 ft. 2 in.) high, with semicircular arch as in Figs. 10 and 11.

The thickness of the revetment varies from 4 to 7 feet, according to both the nature of the ground and the weight of the buildings overhead, one of these buildings being the Royal Palace.

The nature of the ground was very bad, being formed of loose debris and the ruins of ancient Roman buildings, and was often crossed by old sewers, which, in case of rain, carried much water. So the work had to be carried on in very short sections and be lined at once with very heavy timbering followed by blocks of masonry revetment, both for preventing the fall of

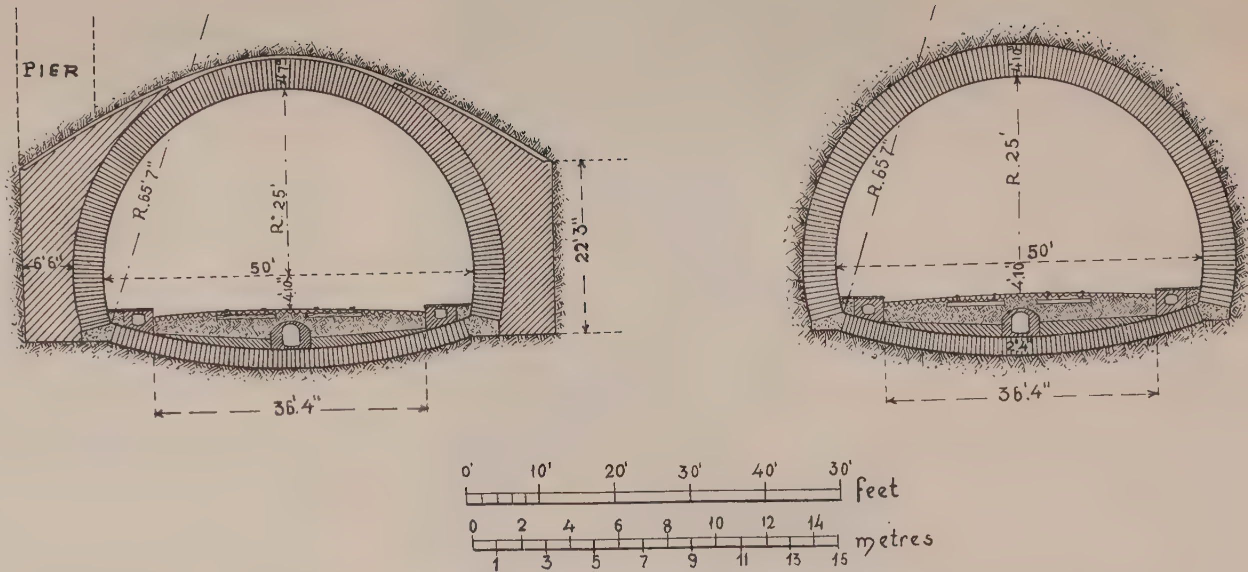
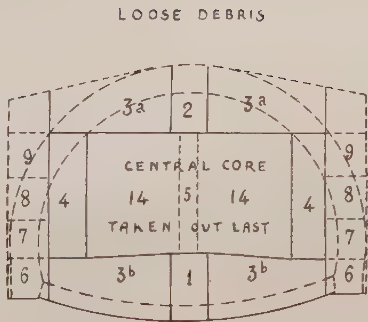
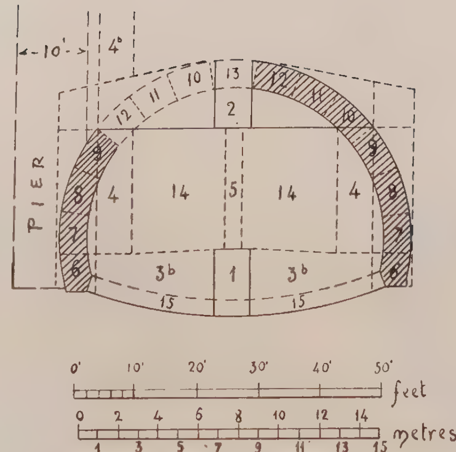


Fig. 10 (left). Quirinal Tunnel in Rome. Section Where Heavy Buildings Had to be Supported on Lateral Piers.
Fig. 11 (right). Quirinal Tunnel in Rome. Sections Under the Royal Gardens, Through Debris of the Old Roman Buildings, Very Loose.





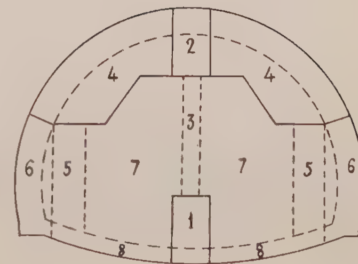


Fig. 12 (left). Quirinal Tunnel. Successive Stages of Perforation and Revetment.

Fig. 13 (center). Quirinal Tunnel. Diagram of Work of Perforation and Revetment Where Heavy Buildings Had to be Supported.

Fig. 14 (right). Quirinal Tunnel. Diagram of Work of Perforation and Revetment Under the Royal Gardens Without Heavy Loads but Through Loose Debris of Old Roman Buildings.

debris and for shoring up the Palace overhead. Even with all possible care and precautions, many settlements and cracks could not be avoided, with the consequence that heavy expenditure for indemnities, compensations and repairs had to be met.

The successive stages in the boring of the tunnel and then lining of it with masonry are clearly indicated in Figs. 12, 13 and 14.

The two portals are richly decorated (Fig. 15) and the inside is lined with enamelled tiles and profusely lighted by electricity.

Fig. 15. View of Eastern Portal of the Quirinal Tunnel in Rome, 50 Ft. Wide.

The pavement was of asphalt, but now is being substituted with ''Soliditit'', a concrete made with a special Portland cement with a very high percentage of silica, forming an exceedingly hard surface, but not slippery.

The work was most successful except in one detail, it is too noisy, and when the traffic of tramways is very intense the noise is almost deafening. This is accounted for by the semi-circular curve adopted for the arch. In the Faro tunnel, in Genoa, where a semi-oval curve was adopted, the noise is much less; but it must also be said there are no tramway lines.

The cost of the whole tunnel, including all decoration and

compensations for damages to buildings, underpinnings, repairs, etc., was 3,500,000 francs ($700,000) or $610 per foot run.

The plans were prepared by Comm. Viviani and carried out completely by Cav. Luigi Botto, C. E., during 1900 to 1902.

CONCLUSIONS.

From the foregoing, we may conclude that tunnels are quite a common occurrence in Italy, where perhaps the finest examples can be found.

Formerly, when they were bored by hand drilling and black powder, an advance at each heading of 2 to 3 feet per day was considered very good.

Since the introduction of compressed-air rock drills, air hammers and dynamite, an advance of 20 feet per day is quite usual; and even 25 to 30 feet per day has been attained in good limestone, when not too hard or too wet. In this kind of work Italian engineers and workmen have quite a reputation and their experience may, perhaps, be of interest to American colleagues.

Paper No. 85

THE RAILWAY TUNNELS OF SWITZERLAND, 1905-1915.

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INTRODUCTION.

Swiss railway legislation distinguishes between "Principal" and "Secondary" railways.

Secondary Railways, according to Art. 1 of the Statutes of December 21, 1899, are those railways and railway portions which specially cater to local traffic or special objects of trade and do not handle the large through-service for passengers and freight.

Accordingly, the Swiss Federal Council, by decrees dated Aug. 10, 1900, and Jan. 24, 1905, defined Secondary Railways as follows:

1. All narrow-gage railways, cog-wheel railways, cable railways, street railways and tramways.

2. A number of specially designated standard-gage railways to which the above given legal definition applies.

All other lines are accounted Principal Railways.

When the construction of a new railway is under consideration, it is determined by Federal law or by an Act of Concession whether or not it shall be classed as a secondary railway.

In regard to the proprietorship of railways, distinction is made between railways belonging to the Government or "Swiss Federal Railway" (S. B. B.), private railways and those railways running across the frontier and subject to foreign administration.

On January 1, 1915, there were:

	In operation	Under construction
Principal Railways..	2557.3 km. (1588.08 mi.)	30.8 km. (19.13 mi.)
Secondary Railways..	2958.2 km. (1837.04 mi.)	302.8 km. (188.04 mi.)
Total	5515.5 km. (3425.12 mi.)	333.6 km. (207.17 mi.)
Of this was		
Double track	860.5 km. (534.37 mi.)	18.3 km. (13.7 mi.)
Lines of the Swiss Federal R. R.	2793.3 km. (1734.64 mi.)	32.2 km. (20.0 mi.)
Private Railways	2668.8 km. (1657.32 mi.)	299.6 km. (186.05 mi.)
Foreign Railways	53.4 km. (33.16 mi.)	1.8 km. (1.12 mi.)
Total	5515.5 km. (3425.12 mi.)	333.6 km. (207.17 mi.)

These figures show 0.133 km. of railway in operation per square kilometer (0.214 mi. per sq. mi.) and 146.3 km. (90.9 mi.) of railway in operation for each ten thousand inhabitants.

The general formation of the country rendered the construction of the railways a task far from easy for the engineers and financiers.

Toward the northwest of Switzerland the Jura Mountains form a range of ridges and valleys between 1000 and 1700 meters (3280-5575 ft.) above the sea; towards the southeast lies the great wall of the Alps with its mountain peaks towering almost 5000 meters (16,400 ft.) above sea-level. Between these two mountain ranges lies the Swiss table-land. It reaches from Lake Leman to the Bodensee, about 50 km. (31 mi.) wide and 250 km. (155 mi.) long, comprising in the neighborhood of 30% of the total area of the country, lying at an elevation from 300 to 500 m. (984 to 1640 ft.), while at the borders and more especially toward the Alps it reaches an elevation of almost 2000 m. (6560 ft.) traversed by some isolated mountain chains.

The water courses, which have cut deep valleys in the Alps, and which the highways follow, also traverse the table-land and present manifold obstacles to roads and railways.

On this account, the number of railway bridges and tunnels, determined by the topography of the country, is very great, and there are certain lines which consist of practically an unbroken series of such constructions.

But the Alps, in earlier times the terror of travelers, are

now penetrated by tunnels among which are the longest in the world and through which a world traffic, safe from land-slides, avalanches, and mountain torrents, flows day and night from north to south and back again.

When we say that the traffic of the world pours through the Alpine tunnels of Switzerland, we speak no idle word,—for does not the mail from Buenos Aires and other South American ports reach New York by way of the Gotthard Tunnel?

Statistically these conditions are shown in the following table:

On Jan. 1, 1915, there were:

	In operation	Under construction	Total
Bridges of more than 2 m. (6.56 ft.)			
clear span	4411	228	4639
with a combined length of	67.722 km.	5.123 km.	72.845 km.
	(42.1 mi.)	(3.2 mi.)	(45.3 mi.)
Tunnels: Number of	575	52	627
Total length, single track	164.628 km.	37.757 km.	202.385 km.
	(102.3 mi.)	(23.46 mi.)	(125.76 mi.)
Total length, double track	70.105 km.	9.138 km.	79.243 km.
	(43.57 mi.)	(5.68 mi.)	(49.25 mi.)
Total	234.733 km.	46.895 km.	281.628 km.
	(145.87 mi.)	(29.14 mi.)	(175.01 mi.)

TUNNELS MORE THAN 2000 m. (6560 ft.) LONG.

Lack of time and space compels us to confine our discussion to Swiss tunnels of more than 2000 m. in length, notwithstanding the fact that in the case of many of the smaller tunnels details of interest might be presented.

First we will present, for the sake of completeness, a table, A, of tunnels over 2000 m. long put into operation before the end of 1904; then a table, B, of tunnels opened since 1905, and finally a table, C, of tunnels more than 2000 meters long still in course of construction in 1915.

Tables B and C contain among other things the principal dimensions of the cross-sections; the profiles are given in the accompanying diagrams.

We will amplify the information given in Tables B and C by a discussion of the most important conditions affecting construction work prosecuted during the last ten years.

Table A—Tunnels in Operation Before Dec. 31, 1904.

No.	Railway	Class	Name of Tunnel	Length m. (ft.)	No. of tracks	Opening day	Remarks
1	S. B. B.	P.	Hauenstein T.	2495 (8186)	2	May 1, 1858	Between Läufelfingen and Olten
2	S. B. B.	P.	Des Loges T.	3259 (10,692)	1	July 15, 1860	Bet. Les Hauts, Geneveys and Convers
3	S. B. B.	P.	Bötzberg T.	2526 (8284)	2	Aug. 2, 1875	Bet. Schinznach, Dorf and Effingen
4	S. B. B.	P.	De la Croix T.	2966 (9731)	1	Mar. 30, 1877	Bet. St. Ursanne and Courgenay
5	S. B. B.	P.	Glovelier T.	2009 (6591)	1	Mar. 30, 1877	Bet. Glovelier and St. Ursanne
6	S. B. B.	P.	Gotthard T.	14,998 (49,206)	2	Jan. 1, 1882	Bet. Göschenen and Airolo
7	S. B. B.	P.	Zürichberg T.	2093 (6867)	1	Aug. 1, 1894	Bet. Zürich-Letten and Zürich Stadelhofen
8	S. B. B.	P.	Albis T.	3359 (11,020)	1	June 1, 1897	Bet. Sihlbrugg and Baar
9	S. B. B.	P.	Musegg T.	2107 (6913)	1	June 1, 1897	Bet. Luzern and Meggen
10	J. B.	S.	Eigerwand T.	2182 (7159)	1	June 18, 1903	As far as Rotstock Aug. 2, 1899; see table B, No. 5
11	Rh. B.	S.	Albula T.	5865 (19,242)	1	July 1, 1903	Bet. Preda and Spinas
12	M. O. B.	S.	Jaman T.	2424 (7953)	1	Oct. 1, 1903	Bet. Les Avants and Allières

Abbreviations: S. B. B.—Swiss Federal Railways
J. B.—Jungfrau Railway
Rh. B.—Rhätische Railway
M. O. B.—Montreux-Oberland Bernois

P.—Principal Railway, standard gage; 1.435 m. (4 ft. 8½ in.)
S.—Secondary Railway. The secondary railways of these tables are all narrow gage; gage 1.000 m. (3.28 ft.)
Bet.—Between the stations.

Table B. Tunnels Put Into Operation Between Jan. 1, 1905, and Dec. 31, 1914.

No.	Railway	Kind and Gage of the Railway M. Ft.	Name of the Tunnel	Length M. Ft.	No. of Tracks	Greatest Width M. Ft.	Arch Height Above Rail Base M. Ft.	Highest Elev. Base of Rail M. Ft.	Opening Day	Location	Remarks
1	S. B. B.	P. 1.435 (4′ 8½″)	Simplon Tunnel I	19803 (64970)	1	5.00 (16.4)	5.50 (18.04)	704.98 (2312.9)	June 1, 1906	Between Brig and Iselle	9084 m. (29800 ft.) under Swiss Jurisdiction
2	S. M. B.	S. 1.435 (4′ 8½″)	Weissenstein Tunnel	3700 (12139)	1	4.80 (15.75)	5.60 (18.37)	722.09 (2369.05)	August 1, 1908	Bet. Oberdorf and Gänsbrunnen	
3	S. B. B.	P. 1.435 (4′ 8½″)	Ricken Tunnel	8603 (28225)	1	5.20 (17.06)	5.80 (19.03)	622.34 (2041.78)	October 1, 1910	Bet. Wattwil and Kaltbrunn	
4	B. T.	S. 1.435 (4′ 8½″)	Wasserfluh Tunnel	3557 (11670)	1	5.17 (16.96)	5.60 (18.37)	657.29 (2156.40)	October 3, 1910	Bet. Brunnadern and Lichtensteig	
5	J. B.	S. 1.000 (3′ 2.8″)	Eigerwand-Jungfrau-joch Tunnel	4931 (16178)	1	3.70 (12.14)	4.050 (13.29)	3457.00 (11341.83)	July 1, 1912	Bet. Eigerwand and Jungfrau-joch	Opened as far as Eismeer 3478 m. (11410 ft.) on July 25, 1905. Total length of tunnel 7113 m. (23337 ft.)
6	B. L. S.	P. 1.435 (4′ 8½″)	Lötschberg Tunnel	14612 (47939)	2	8.00 (26.25)	6.00 (19.68)	1242.70 (4077.09)	July 15, 1913	Bet. Kandersteg and Goppenstein	
7	Rh. B.	S. 1.000 (3′ 2.8″)	Tasna Tunnel	2350 (7710)	1	4.30 (14.11)	5.00 (16.40)	1385.00 (4543.95)	July 15, 1913	Bet. Ardez and Fetan	

Table C. Tunnels Still in Course of Construction, Jan. 1, 1915.

No.	Railway	Kind and Gage of the Railway M. Ft.	Name of the Tunnel	Length M. Ft.	No. of Tracks	Greatest Width M. Ft.	Arch Height Above Rail Base M. Ft.	Highest Elev. Base of Rail M. Ft.	Opening Day	Location	Remarks
1	P. L. M.	P. 1.435 (4′ 8½″)	Mont d'Or Tunnel	6097 (20003)	2	8.60 (28.21)	6.10 (20.01)	898.09 (2946.47)	May 16, 1915	Bet. Les Longeville and Vallorbe	989 m. (3245 ft.) under Swiss Jurisdiction
2	S. B. B.	P. 1.435 (4′ 8½″)	Hauenstein-Base Tunnel	8134 (26686)	2	8.40 (27.56)	6.20 (20.34)	451.93 (1482.70)	Probably January 1, 1916	Bet. Tecknau and Olten	
3	B. L. S.	P. 1.435 (4′ 8½″)	Grenchenberg Tunnel	8565 (28100)	1	5.20 (17.06)	5.80 (19.03)	545.05 (1788.21)	October 1, 1915	Bet. Münster and Grenchen	
4	S. B. B.	P. 1.435 (4′ 8½″)	Simplon Tunnel II	19825 (65042)	1	5.00 (16.40)	5.50 (18.04)	704.98 (2312.90)	Probably May 1, 1918	Between Brig and Iselle	9075 m. (29770 ft.) under Swiss Jurisdiction

Abbreviations: S. B. B.—Swiss Federal Railways
S. M. B.—Solothurn-Münster Railway
B. T.—Bodensee-Toggenburg Railway
J. B.—Jungfrau Railway
B. L. S.—Bern-Lötschberg-Simplon, Bern Alpine R. R. Co.
Rh.B.—Rhaetian Railway
P. L. M.—Paris-Lyon-Mediterranean Railroad
P.—Principal Railways
S.—Secondary Railways
Bet.—Between the stations.

THE SEVERAL TUNNEL UNDERTAKINGS.

1. **The Simplon Tunnels I and II.** (No. 1, Table B and No. 4, Table C).

Tunnel I. The Simplon Tunnel I, 19,803 m. (64,970 ft.) long, is the longest mountain tunnel in the world. Running from northwest to southeast, with two short junctional curves respectively of 320 and 400 meters (1050 and 1310 ft.) radius, the rest on a tangent, it bores through the huge bulk of Mt. Leone [3561 m. (11,683 ft.) altitude] which divides Switzerland from Italy, between the stations of Brig on the north side and Iselle on the south. The history of the whole undertaking, its geological aspects, the work of the survey, the installation and the construction have been presented in detail in various publications by distinguished experts. We would refer all those interested in the subject to the attached list of references and confine ourselves to the most important data indispensable as a basis for comparison with other construction work of this type.

For forty years the authorities and contractors had striven to make clear the technical problems involved and to overcome the financial and political difficulties which opposed the work of construction.

Actual work was finally begun in 1898 on the basis of a plan submitted in 1893 by the firm of Brandt, Brandau & Co., and on the basis of a forfeiture contract entered into by a syndicate composed of Engineers A. Brandt and K. Brandau, the Bank of Winterthur and the firms of Sulzer Bros. and Locher & Co.

The contract stipulated that the temperature in places where work was going on should not register above 25° C. That the influx of water was to be rapidly drained off from stretches where construction was in progress, and, that where difficulties presented themselves in connection with rock excavation, etc., the most favorable possible conditions both for the carrying out of the work and for the men employed were to be maintained. This caused the contractors to choose the two-tunnel method of construction, which, based on the experience gained in the construction of the 14,998-m. (49,206-ft.) long St. Gotthard Tunnel (1872-1881), at that time had been

first recommended by W. von Pressel for the construction of longer and deeper tunnels. The distance between centers of the two single-track tunnels was fixed at 17 m. Only the eastern tunnel, No. I, was to be completed. Of Tunnel II, on the west, only a bottom heading was to be driven, lying on the eastern side of the finished cross-section, and serving for ventilation and for running in empty work trains. It was to be masonry lined as far as necessary to ensure its safety.

Hydraulic drills, Brandt system, were to be used for the mechanical drilling.

The survey of the axis of Tunnel I was carried out after the plan of the survey of the Gotthard Tunnel in a most careful manner, commensurate with the importance of the work, by means of a tying in of the axis points on both sides, as given by the construction plans, with a triangulation extending over the mountain. This survey, on its part, was connected to one side of the geodetic triangulation which connected the Simplon Astronomical Station with the points of the first order of the Swiss Survey. The minute direct measurement of a base line to close the triangulation was thereby saved.

The geological conditions (what now seems surprising) were, before the beginning of construction, very insufficiently understood, and on that account and owing to the sequence and nature of the rock formation, influx of water and temperature conditions, difficulties entirely unexpected and unpredicted were encountered in connection with the driving of the heading. Thus the tunnel traversed, instead of a simple gneiss formation, a section of the most complicated stratification, and at a point 10 kilometers (6.2 mi.) from the north portal, where it was expected the tunnel would be in the middle of the Mt. Leone gneiss, it ran, first, into Triassic marble and anhydrite and then into Jurassic limestone and slate which extended more than 3 km. (1.8 mi.). Altogether there were about 11.3 km. (7.0 mi.) of different kinds of gneiss and 8.5 km. (5.3 mi.) of marble, gypsum, anhydrite, limestone and slate of the Triassic and the Jura. Ten kilometers (6.2 mi.) from the north portal, where the excavation, according to expectation, should have been dry, hot springs were encountered with a discharge of about 300 second-liters (10.6 sec-ft.), and instead of the expected 38°-39° C., the

temperature rose to 54.5° C. In the Teggiolo marble, which it was expected to encounter about 7 km. (4.3 mi.) from the south portal, but which was actually encountered 4.3 km. (2.7 mi.) from it, cold springs were met with of more than 1000 second-liters discharge (35.3 sec-ft.). More than one month was occupied in traversing these 60 meters (197 ft.) of water-bearing strata and the end had barely been reached when another difficulty presented itself in the shape of a tremendous rock pressure from every direction. For this stretch of 42 m. (138 ft.) the heading had to be driven with centers made of 400 mm. (15.7 in.) I-beams bolted together and the spaces between filled with concrete. Here for almost seven months the drills were idle. On the south side there was also encountered a region of hot springs, where the final stretch of 245 m. (804 ft.) of heading consumed almost six months.

That this great number of difficulties was overcome, thanks are due to the painstaking and liberal planning of the equipment, the method of construction chosen, the wonderful organization and the extraordinary energy of the contractors, as well as to the cooperation of the highest authorities of the country. In fact the Federal Council guaranteed to the Jura-Simplon Railway at the time of its absorption by the State (1903), an indemnity to cover the increase of price which the Railway Company had to pay the contractors in order that they might be able to carry on and complete the work.

Hydraulic power plants, with turbines of 2100 hp.* on the north side and of 1100 hp. on the south side, furnished the power for operating the various installations. In order to ensure uninterrupted work, semi-portable steam engines were provided. Particularly worthy of mention is the 3200 m. (10,500 ft.) reinforced concrete head-race at the water-power plant on the north side.

In the neighborhood of each tunnel portal stations were maintained containing everything necessary for the prosecution of the work; also the machinery for drilling and for the ventilation of the tunnel, the work-rooms for repair of machines and tools, store-rooms, sheds for coal and rolling-stock, shelter and accommodations for the employees and workmen, baths,

* 1 metric horsepower equals 75 meter kg. per second.

hospitals and administration buildings; and, last but not least, every contrivance for the conveyance of the workmen, the construction material and the spoil.

High-pressure pumps delivered water, about 36 second-liters (1.27 sec.-ft.) on each side, at 70 to 100 atmospheres pressure for the operation of the rock drills and the ventilation and cooling in the heading itself. Ingersoll and Burckhardt & Co.'s air-compressors gave an air-pressure of 100 atmospheres for supplying the tunnel locomotives. Two fan blowers were installed on either side for ventilating the headings. Each supplied 25 cubic meters (882.9 cu. ft.) per second with a pressure of about 250 mm. (10 in.) of water. They could be operated for suction or compression and regulated for volume or pressure. An electric crane of 4000 kg. (8818 lbs.) capacity was provided on the north side for unloading the spoil trains. At both ends there were built about 13.5 km. (8.4 mi.) of 0.80-m. (31½-in.) gage track.

Since the air was conducted through Tunnel II and through the last cross drift to Tunnel I, those portions of the heading lying behind the last cross drift had to be supplied at the face with fresh air by means of a special arrangement known as "secondary ventilation". To this end, two small ventilators were installed in heading II. Each gave about 0.75 cubic meters (26.5 cu. ft.) per second of air with a pressure of 500 mm. (19.7 in.) of water. They were operated by turbines of 10 hp., which were driven by water taken from the high-pressure water supply for the drills. Fresh air was also supplied right at the heading by means of water jets, but this worked less economically. For cooling the air, new plants were necessary, as it was shown with the progress of the tunnel that the anticipated temperature of 42° C. was greatly exceeded. Two special turbines of 300 hp. each drove two high-pressure centrifugal pumps, each one of which delivered 80 liter-seconds (2.82 sec-ft.) of water at 22 atmospheres pressure. The cooling water was brought into the tunnel in separate pipes and served for the operation of the dust-sprinkling apparatuses, by which the compressed air forced into the tunnel was lowered 10° or 12° C. In the conduit for the secondary ventilation an ice car was introduced, which served not only to cool but also to dry the

air. The lowering of the temperature produced by ventilation and cooling corresponded to a removal of heat of about 2,332,-000 calories per hour (9,250,000 B.t.u.).

The Brandt drill, which in the course of time has been greatly improved by Sulzer Bros., has as a distinguishing feature a hollow circular cutting tool made of the best hardened and tempered steel, 65 mm. (2.6 in.) outside diameter and 30 mm. (1.2 in.) inside diameter, with three teeth on its edge.

This tool is forced against the rock with a pressure rising at times to a maximum of about 15,000 kg. (33,000 lbs.) and at the same time is slowly turned.

A part of the operating water flows through the bit, cools it and washes out the cuttings. In the driving of the headings it was customary to fasten three machines on a beam across a drill car. In the cross drifts only one drill was used, as a rule; all other excavation was done by hand drilling. Ten to twelve holes were drilled on an average for each set-up, which resulted in a progress of from 1.00 to 1.30 m. (3.28 to 4.27 ft.). Ordinarily four or five set-ups were made daily. The consumption of dynamite with machine drilling ran 4 to 6 kg. per cubic meter of excavation (6.7 to 10.1 lbs. per cu. yd.) and with hand drilling 0.6 to 0.7 kg. (1.0 to 1.2 lbs.) or 1.5 to 2 kg. per cubic meter on an average (2.5 to 3.4 lbs. per cu. yd.).

An attempt to throw back the loosened stone from the face of the heading by means of jets of water applied during the explosion of the charges, and thereby make it possible to set up the drills again more quickly, did not give the hoped-for results; but the contractors succeeded in devising other practical means for lessening the time required for mucking and clearing away.

From the bottom heading of Tunnel I, complete excavation was accomplished by an upraiser with a top heading run forwards and backwards, enlargement to full arch section and excavation of the lower benches; after this the lining of the side walls in ashlar and of the arch in courses was carried out. For the masonry lining, artificial stones of only about 80 to 140 kg. per sq. centimeter (1138 to 1990 lbs. per sq. in.) compressive strength were employed. The masonry lining of stretches in the water-bearing strata, especially where pressure was encountered at

Km. 4.45 to 4.492 (2.76 to 2.79 mi.) gave unusual difficulty. In the latter instance, an invert 2.50 to 2.80 m. (8.2 to 9.2 ft.) thick and a four-course arch of cut stone, 1.67 m. (5.48 ft.) thick at the crown, laid in cement mortar had to be built.

The iron frames had to be cut through and it was necessary to proceed in small sections with the greatest care in order to avoid, as much as possible, new movements of the rock or manifestations of pressure. This work consumed more than a year's time. In the middle of the tunnel, heading II was widened to full size and connected with Tunnel I by two diagonals. In this manner a crossing station 500 m. (1640 ft.) long was constructed. This station was fitted up with the necessary signals and safety devices and ever since the opening of the road has been occupied by officials.

The north locating heading of the tunnel was begun on Aug. 1, 1898—the south on Aug. 16 of the same year. The rate of progress on the north side reached a maximum of 7.25 m. (23.8 ft.) per day in July, 1903, and on the south side a maximum of 7.93 m. (26 ft.) per day in June, 1902. Owing to a strike, the work was interrupted for one day in 1899 and fourteen days in 1901. The holing through occurred at 7:20 A. M. the morning of February 24, 1905, at 9.385 km. (5.83 mi.) from the south portal. The control of the axis showed a variation in alignment of about 202 mm. (8 in.), a difference in elevation of 87 mm. (3.43 in.), and an excess of length over that computed of 0.70 m. (27.6 in.). The arch in Tunnel I was united October 18, 1905, 2635 days after the beginning of the excavation. This shows a daily progress of 7.51 m. (24.6 ft.) of finished tunnel. The last rails were laid in January, 1906, and finally various cables, of a total length of 110 km. (68.35 mi.), were installed in about ten days more. On the 21st and 22nd of February, 1906, the tunnel was taken over by the Swiss Federal Railways and opened for traffic June 1, of the same year.

Special mention is due the firm of Brown, Boveri & Co., who made an agreement on Dec. 19, 1905, with the management of the Swiss Federal Railways, and by the end of May, 1906, had equipped the tunnel and the approaches, as well as the stations of Brig and Iselle, with a three-phase 3000-volt current for the electric operation, at their own risk and expense. For the

application of this system, it was necessary that the Italian State Railways should place at the disposal of the Swiss Federal Railways the electric locomotives which could be operated with this form of electric current and which were designed for the Valtellina lines.

The daily average number of laborers reached its maximum on the north side in the third quarter of 1900 with 1953 men, of whom 1500 were employed in the tunnel. On the south side, the maximum was reached in the third quarter of 1904, with 1939 men, of whom 1386 were employed in the tunnel.

Altogether there were required in the construction of the tunnel, including its own equipment and whatever buildings there were outside of it, on the north side (Brig) 3,448,425 days' work, and on the south side (Iselle), 3,603,005 days' work, or a total of 7,051,430 days' work.

There were fifty-one fatalities. With respect to sickness, it is to be remarked, that thanks to the thorough hygienic measures in the tunnel and environs, that dreaded disease of miners, Anchylostomiasis due to the so-called "tunnel worm" (*Anchylostomum duodenale*), did not make its appearance.

By the workmen on the north side, mostly Italians, there was sent home by postal order, during the years 1899-1905, 2,154,661 Fr. ($415,850) and a sum no less was probably brought home personally.

The cost of Tunnel I, including the bottom heading of Tunnel II, stood, at the end of 1913, at 58,500,000 Fr. ($11,290,500), or about 2,954 Fr. per meter ($173.83 per ft.).

Tunnel II. Under the terms of an agreement dated April 15, 1898, and an amendment dated October 9, 1903, the tunnel construction firm of Brandt, Brandau & Co., was bound to build the second tunnel without ballast and superstructure for the sum of 19,500,000 Fr. ($3,763,500) in the same way as Tunnel I had been built, provided they were given the contract within two years following the completion of the work in Tunnel I. On Jan. 3, 1908, within the specified time, they were awarded the contract, and the General Management of the Swiss Federal Railways granted, through the authorities, a sum of 34,600,000 Fr. ($6,677,800) for the completion of the whole work. The contractors explained that they were unable to carry out the

construction of Tunnel II for the contract price and refused to make any guarantee for the safety of Tunnel I during the construction of Tunnel II.

After lengthy negotiations the Construction Company was released from the contract. In the meanwhile bids were called for. The prices ranged between 25,500,000 Fr. ($4,921,500) and 47,000,000 Fr. ($9,071,000), wherein the bidders to be given consideration stated that safety for Tunnel I could not be guaranteed. At last the board of administration of the Swiss Federal Railways decided, on July 19, 1912, to carry out the work as a departmental construction. Mr. F. Rothpletz was selected as Director of Construction. He had already been employed on Tunnel I and since then had held important positions on the tunnel work in the Weissenstein, Lötschberg and Grenchenberg tunnels.

The length of Tunnel II was	19,825 m. (65,042 ft.)
Of which there was already finished in the construction of Tunnel I	649 m. (2,129 ft.)
Leaving still to be constructed	19,176 m. (62,913 ft.)

The construction began with the erection of the outside plant in December, 1912. The top heading was begun on the north side on Dec. 20, 1912, and on the south side April, 1913. The widening and the masonry followed close upon the headings. The Meyer system of air drills was used. In each drift about 40 drills were operated, on an average, when the work was under full headway, in the year 1914. For the arch and in parts of the walls, in those stretches where there was not much pressure, there was used an artificial stone, manufactured in Brig, with a compressive strength of at least 260 kg. per sq. cm. (3700 lbs. per sq. in.).

Compressed-air and storage-battery locomotives are used inside and steam locomotives outside the tunnel. Until July 15, 1915, ventilation was provided by the equipment used for the service of Tunnel I. Since then a new and larger plant, in connection with the power station for the electric haulage of trains, is in operation on the north side. It delivers 90 cubic meters (3178 cu. ft.) per second for Tunnel I and 25 cubic meters (883 cu. ft.) per sec. for the north heading of Tunnel II. The southern workings will be ventilated from Iselle. The highest temperature encountered was 24° C. on the north side in July, 1914.

The Director of departmental construction was able to proceed most advantageously, because, having had the benefit of experience during the construction of Tunnel I and the heading of Tunnel II and knowing meter for meter just what rock would be encountered and what difficulties would have to be overcome, he was able to select at will the number and position of the workings. Hence the construction of the difficult stretch at Km. 4.352 to 4.500 (2.70-2.795 mi.) from the south portal was begun in May, 1913, in order to have this completed before the regular driving of the tunnel from the portal reached that point. In that way the adjoining stretches of about 100 m. (328 ft.) on each side of the proper pressure stretches were completed; with this the stretch lying in the dolomite region of cold springs at Km. 4.352 to 4.452 (2.70 to 2.765 mi.); after that the pressure stretches passing through the soft limestone and mica-schist, at Km. 4.452 to 4.500 (2.765 to 2.795 mi.) were undertaken in the following order:

1. Invert blocks were placed the entire length of the pressure stretch, with carefully built masonry foundation for the iron centers in the bottom heading.

2. Building the side walls for the entire length and concreting the spaces between the iron frames and the rock walls.

3. Excavation of the arch and lining with masonry.

4. Removal of the iron frames, installation of the conduits and leveling up of the bottom with concrete.

In order not to release the latent pressure of the mountain, two things were necessary—rapid work and the immediate filling of the hollow spaces.

The work progressed favorably. Begun December, 1913, it was hoped that the last arches could be united at the end of April, 1914. About the middle of April, with still three 4-meter (13.1 ft.) rings of the arch open and two courses in the wall on the point of completion, certain agitators decided that it was the psychological moment to start a victorious strike. The management sought to insure provisional safety for the unfinished places and answered, on the 18th of April, with a complete suspension of work; already on the 26th of the same month the work was unconditionally resumed and brought to a satisfactory completion on the 29th of May, 1914.

The work in Tunnel II only slightly affected Tunnel I along the pressure stretches. On the other hand, the so-called "shelling" of the rock met with in the construction of Tunnel I repeated itself in the Antigorio gneiss from the south portal up to Km. 4.380 (2.72 mi.). Flakes and slabs would fly off with a loud report from the living rock. This would occur without any warning and there is no known method of avoiding it. It must be attributed to the release of internal stress existing in the mountain. Such a "shelling" of rock caused considerable dislocation of the conduit, side wall and arch of Tunnel I, in July, 1914, at Km. 3.300 (2.05 mi.) from the south portal. The western wall had to be replaced and strengthened for a length of about 25 meters (82.0 ft.). The reconstruction of the arch and the placing of an invert must be deferred, if possible, to the time when the train service can be transferred to the completed second tunnel.

Owing to the mobilization of the Swiss army on Aug. 3, 1914, the greater number of the workmen were dismissed and the work confined to a short stretch along which the completion of the masonry lining was necessary to insure the safety of Tunnel I.

By the end of December, 1914, 8942 m., or 43.6% of the entire tunnel was completed. The total number of days' work since the beginning of construction was 1,041,129. The number of fatalities was four.

In January, 1915, the work in the tunnel on the south side was taken up again. Work on the north side is still in abeyance at the time of this report.

The cost of lining the 52 meters (171 ft.) of pressure stretch, inclusive of the safe-guarding of Tunnel I, was given by Chief Engineer Rothpletz at 370,673 Fr. ($71,539), or 7128.32 Fr. per meter ($419.44 per ft.). The driving of the second heading has probably cost about the same amount.

The total cost of the completed Tunnel II is estimated at 27,500,000 Fr. ($5,307,500). This figure would place the cost of the completed double tunnel, without ballast, track and electric installation, at 86,000,000 Fr. ($16,598,000) or about 4338 Fr. per meter ($255.25 per ft.).

2. The Weissenstein Tunnel. (No. 2 of Table B.).

The Weissenstein Tunnel, 3700 m. (12,139 ft.) of single track, on the line of the Solothurn-Münster standard-gage branch, pierces in the Jura Mountains the two-fold lines of the Weissenstein and the Graitery chains between the stations of Oberdorf and Gänsbrunnen, and passes under the valley of Gänsbrunnen between these two mountains.

The establishment of the tunnel axis was accomplished by a direct survey over the mountain; the length of the tunnel was determined by triangulation.

Construction was commenced the end of 1903; the holing through occurred on September 23, 1906, and the completion at the close of 1907. Of the entire length, 3518 meters (11,542 ft.) are on a grade of 1.8% and the remaining 182 meters (597 ft.) are horizontal. The steepest grade on the open road is 2.8%.

As a system of construction, the driving of a bottom heading at sub-grade level of 6 sq. meters (64.58 sq. ft.) cross-sectional area was chosen. From the bottom heading uprisers were driven to the top of the arch; later followed the construction of a top heading, then widening above the spring line to full section, excavation of the lower section and lining with masonry. Next the short horizontal portion on the north side was undertaken by hand drills. Inasmuch as the water conditions proved favorable, the heading was carried over to the reverse grade and passed under the Gänsbrunnen Valley, where floods of mud and water, and then a cave-in, occurred. At Km. 0.294 (0.18 mi.) from the north portal, work on this side was suspended. On the south side the drilling was done with percussion drills, which were operated at a pressure of about 7 atmospheres. In the bottom heading there were usually in operation three drills of 90 mm. (3.55 in.) diameter on a drill carriage, mounted on a horizontal drill shaft fastened securely against side and roof by hand screws.

The compressed-air pipes had a diameter of 90 mm. (3.55 in.) from the plant to a point about 30 m. (98.4 ft.) from the face of the heading and from there a diameter of 50 mm. (1.97 in.). A water pipe of 38 mm. (1.5 in.) diameter delivered the necessary water for washing out the drill holes.

In traversing the foldings of the Jura Mountains all the characteristic and various strata belonging to the Trias, Lias, dogger and malm formations were encountered, such as gypsum-keuper, dolomite, opalinus clay, oolite, Portland-marl, Effinger and Geissberger lime, oolitic spar, Kimmeridge lime, etc. At the south portal and in the Gänsbrunnen Valley, the Tertiary conglomerates, fresh-water limestone and molasse, the latter for the most part in the form of marls, and a short stretch of Quarternary moraine were encountered. The mountain was highly metamorphosed and demanded, especially in the marl and anhydrite strata and opalinus clays, either immediate or subsequent lining.

Owing to the frequent inrushes of water, which reached at times 450 second-liters (15.9 cu. ft. per sec.), the work was often delayed and rendered more difficult. In October, 1904, when the work was uninterrupted, an average daily progress was made of 6.50 m. (21.3 ft.) and a maximum of 8 m. (26.2 ft.). For the whole construction time the average monthly headway in the bottom heading on both sides together was about 113 m. (371 ft.).

The control of the tunnel axis taken after joining the two headings showed a lateral deviation of 49 mm. (1.93 in.), a difference in elevation of 11 mm. (0.43 in.), while the actual length of the tunnel was 0.66 m. (2.165 ft.) shorter than the calculated length.

The tunnel was ventilated by three Sulzer ventilators arranged in series.

The air pipes in the finished tunnel had a diameter of 600 mm. (23.6 in.). Pipes of 350 mm. (13.8 in.) diameter were laid in the neighborhood of the heading and provided with sheet-metal protection as far as was necessary. The air temperature in the headings was from 11° to 13° C, the temperature of the springs from 8.50° to 9.50° C.

The necessary machines and workshops for the construction of the tunnel were installed at the south entrance; at that place there were also installed the necessary welfare and safety arrangements for the workmen.

Wangen, on the River Aare, furnished the electric power.

Masonry lining was anticipated for only 50% of the length

of the tunnel. In actual fact, the tunnel had to be lined completely for a distance of 3025 meters (9924 ft.) and partially for a further distance of 297 m. (974 ft.), or altogether 87% of its entire length. There remained, altogether, a total distance of 478 m. (1568 ft.) unlined, or 13%. After the tunnel was opened for traffic it was necessary, in the Molasse marl region at Km. 2.9-3.4 (1.8 to 2.1 mi.) from the south portal, to construct an invert and to grout the roof arch in certain places for the purpose of making it watertight.

For the most part the masonry lining was a light stone section, partly with footings for the invert; a stronger section was used only for a distance of about 32 meters (105 ft.) through the stretch of moraine. The stone work, consisting of limestone, was set in hydraulic-lime mortar and in wet places in cement mortar.

Later on, in the completion of the arch, cast concrete blocks were used.

The cost of the completed tunnel, inclusive of the additional work taken over by the Railway management, amounted to 3,691,273 Fr. ($712,415.68) at the end of 1914, or about 998 Fr. per running meter ($58.68 per ft.).

3. The Ricken Tunnel. (No. 3 of Table B.)

This tunnel is 8603 meters (28,225 ft.) long, single track and on a tangent. It lies between the stations of Kaltbrunn and Wattwil on the Uznach-Wattwil line which connects the basin of Zürich Lake with the valley of the Thur.

The longitudinal profile shows a grade of 1.575%, all on the north side, while the maximum grade of the whole line is 2.0%. The survey of the tunnel was carried out by means of a tying in of the established points on the axis in the neighborhood of the tunnel mouth with the governmental triangulation. The bench mark for leveling was tied in with the government levels. The two approaches and portals of the tunnel lie in loose earth and moraine. For the remaining distance the tunnel traversed the so-called ''Ebnater'' and ''Bildhauser'' strata formed of sandstones and marls and belonging to the lower Süsswassermolasse of the pre-Alpine period.

The first 300 meters (984 ft.) were opened up with a top heading and constructed according to the Belgian method. The

remaining 8300 meters (27,230 ft.) were carried on with a bottom heading. On the south side to a point about 2220 meters (7282 ft.) from the portal, the bottom heading was 1.45 meters (4.76 ft.) above the bottom of the tunnel; for the remaining 6080 meters (19,947 ft.) it lay on the bottom of the tunnel itself. The first plan, which involved the laying of the walls and the use of many tracks at the same time, was not satisfactory and was abandoned in favor of the second method. By this method the top cut uprisers followed the bottom heading in two stages, then widening above the spring line to full section, excavation of lower section, and the masonry lining of the side-walls and arch. In the pressure stretch of about 200 m. (656 ft.) long, at point 3.230 km. (2.0 mi.) from the north portal, after the bottom heading was carried up, the two side lower sections were stoped out and the side walls were laid up in masonry, so that until the excavation of the arch section, some four weeks later, its entire weight was carried on the wood centers. This was followed by earth motions, cracks, and contractions in the completely walled tunnel to such an extent that the entire reconstruction of the masonry of this stretch was necessary.

The heading had a cross-section of from 6.0 to 6.2 sq. m. (64.58 to 66.74 sq. ft.). Excavation was accomplished by hand, in hard chalky sandstone with the customary two-man drill, in the soft marl with ratchet drills similar to hand drills, which drilled 1.00 to 1.20 meters (3.28 to 3.94 ft.) of hole in thirty minutes. Dynamite was used for blasting purposes.

A roof-lagging was, for the most part, sufficient in the heading. The average daily progress in driving the heading was 2.7 to 3.6 meters (8.86 to 11.8 ft.). On account of a strike, work in the headings was suspended from July 3 to Aug. 1, 1904. Begun in January, 1904, the headings were holed through on the 30th of March, 1908, at 4.400 km. (2.73 mi.) from the south portal. The final measurements showed a lateral deviation of the two axes of 155 mm. (6.1 in.), a difference in height of 28 mm. (1.1 in.) and a difference in length of 0.19 m. (0.62 ft.). The tunnel was completed in July, 1910.

The tunnel is lined entirely with masonry. The material used is lime-sandstone of about 1330 to 1350 kg. per sq. cm. (18,900 to 19,200 lbs. per sq. in.) compressive strength. In the

dry stretches hydraulic-lime mortar was used, and in the pressure stretches and wet portions Portland cement. The average monthly headway along the arch was 102 to 105 m. (335 to 344 ft.), the maximum 162 m. (531 ft.).

Plants for the necessary ventilation, motors, pumps, etc., were established at both ends of the tunnel. Telephone communication connected the workings with the plants. Air was supplied through pipes of decreasing diameters of 80, 60, 40 and 35 cm. (31.5, 23.6, 15.8 and 13.8 in.) to the face of the headings. Air and rock temperatures ranged between 17° and 22° C. While, in accordance with the geological predictions, work was hindered by no great inflow of water, nevertheless in the driving of the locating heading and the widening, fire-damp, or Methane (CH_4), was met with most unexpectedly on many occasions. These gas sources were characteristic of the lignite strata lying in the sandstone (Molasse) region. The appearance of this gas necessitated interruptions and disturbances in the work of construction. On the 9th of March, 1907, on the north side 42 meters (138 ft.) back of the face or at Km. 4.141 (2.57 mi.) where widening was proceeding, an exceptionally strong gas source was cut into. This gas, burning with a broad, thick flame about 1 meter (3.28 ft.) long, necessitated, on account of the great amount of heat produced, a suspension of the work and a lagging up of the roof of the rear stretch of marl, where, owing to the drying out of the rock, considerable stone was loosened. Though the intensity of the escaping gas ceased rather quickly, the work remained stationary at Km. 4.203 (2.61 mi.). On March 28, 1907, at Km. 3.799 (2.36 mi.) a strong gas source was encountered on the south side and ignited by the blasting. This occurrence, unique in the construction of Swiss tunnels, occasioned a longer suspension of the work. To protect the workings lying behind, the burning portion was shut off by a bulkhead 12 m. (39.4 ft.) thick, so that when the air was shut off the fire went out. Two pipes, provided with valves and located in the bulkhead, served the purpose of sampling periodically the gas discharged as to composition and pressure. The result showed a content of Methane of 91% to 92% and a pressure of 12 mm. (0.47 in.) of water. At Km. 3.524 (2.19 mi.), that is, as far as the tunnel was supported by wood, excavation

and masonry were carried on and finished. After that the work was confined to the installation of the necessary apparatus for the removal of the imprisoned gas.

After this was accomplished—by the middle of October, 1907—and the wall and earth dam removed, the construction of the heading was resumed on the 22nd of the same month. By means of a copious supply of air (about 5 cubic meters [176 cu. ft.] per second), the use of safety explosive (Grisoutine), safety lamps, electric lighting, suspension of all other work in the tunnel during the driving of the heading, the exclusion of steam locomotives from the tunnel, construction of air-tight trap-doors and refuge stations for the laborers, provision of life-saving apparatus (oxygen equipment) and bandages, it was endeavored to avoid all the perils consequent upon the prosecution of the work. Owing to this there was no loss of life to be regretted on account of further escape of gas.

The number of days' work consumed in the construction of the tunnel was 1,521,978. There were seventeen fatalities.

The cost of construction of the Ricken Tunnel was 12,867,200 Fr. ($2,483,370), or about 1495 Fr. per meter ($88.00 per ft.).

4. The Wasserfluh Tunnel. (No. 4 of Table B.)

The Wasserfluh Tunnel of the Bodensee-Toggenburg Railway, 3557 m. (11,670 ft.) long, lies between the stations of Brunnadern and Lichtensteig, connecting the Necker and the Thur Valleys. The tunnel is single track; it runs in a straight line with the exception of a curve of 400 m. (1312 ft.) radius and about 400 m. (1312 ft.) long at the eastern portal and has a grade of 1.04% toward the west portal at Lichtensteig. The maximum grade of the outside line is 1.85%. The survey of the axis was accomplished by means of auxiliary points on top of the mountain. The length of the tunnel was ascertained without direct triangulation by means of a calculation of the coordinates of the axis points surveyed on both sides and tied in to the triangulation of the canton. The elevations were determined by double levels and by trigonometric computation as well.

For almost its entire length the tunnel passes through dense conglomerate occasionally intersected by seams of marl.

The order of construction consisted in the driving of a bottom heading of about 8 sq. meters (86.11 sq. ft.) cross-section, driving uprisers, top cut, widening to full arch section, excavation of lower section, and laying the masonry of the walls and arch.

Owing to the grade being on one side, the principal part of the work was concentrated at the west portal on the up grade and machine drills installed here. Hand drills only were used on the east side. A plant was therefore installed suitable to each end of the tunnel. The machine drilling was done by three pneumatic percussion-drills of the Bechem and Keetmann pattern, mounted on a horizontal cross-bar; for the widening and trimming, H. Flottmann & Co.'s drills were used. One drill, with a working pressure of from 4 to 6 atmospheres, makes 190 blows per minute of 225 mm. (8.86 in.) stroke, using about 3 cubic meters (105.9 cu. ft.) free air and bores 1 meter (3.28 ft.) of drill hole in the hard tough rock in about 13 minutes. A meter of the heading required 15 to 20 kg. of dynamite (10 to 13.5 lbs. per ft.); the average daily headway was 3.50 to 4.50 meters (11.5 to 14.8 ft.). The hand drills gave a similar headway of 1.30 to 1.50 meters (4.26 to 4.92 ft.). A percussion drill, with a weight of about 13 kg. (28 lbs.) and a stroke of 25 mm. (0.98 in.), made a meter (3.28 ft.) of bore hole of 23 to 30 mm. (0.9 to 1.18 in.) diameter in hard rock in 18 to 20 minutes (1 ft. in 6 min.).

Timbering was necessary in only a few places, particularly where the top heading was being driven in marl strata. The ventilation of the west heading, attempted by means of the use of two Sulzer ventilators No. VII, was hardly sufficient and had to be increased before holing through by the introduction of two pneumatic injectors into the air conduit, which, on account of being operated by compressed air, could only work when the drills were not running. The tunnel is lined with masonry for its entire length, for the most part only 40 cm. (15.7 in.) thick. There were no pressure stretches; on the other hand, at 2.280 km. (1.42 mi.) from the west portal a water cavity was cut into, which, flooding the tunnel, quickly spent itself; the remaining flow decreased to about 10 liter-seconds (0.35 sec-ft.). Lime-sandstone and lime conglomerate were used for the masonry,

laid in hydraulic lime, and in the wet places, in cement mortar. One portion of the wall was built of concrete 1:3:6; some hundred meters of the arch, of concrete blocks 1:2:5 set in cement mortar. Particularly notable is the construction of economizing arches in the side walls.

The bottom heading was commenced the end of December, 1905; the holing through followed on the 2nd of April, 1909, at 2419.55 m. (7938 ft.) from the west portal.

The control showed a lateral deviation of the two axes of 50 mm. (1.97 in.) and a difference in elevation of 10 mm. (0.39 in.); the measured length was 0.28 m. (0.95 ft.) longer than the calculated length.

The masonry lining was completed on the 6th of May, 1910. The average daily number of workmen reached a maximum in September, 1909, with 743 men.

It is to be noticed in passing, that the work was carried on as departmental construction from the end of December, 1905 until April 30, 1907. A contracting firm operated from May, 1907 until June, 1908. This firm had to undergo two strikes, and on account of insufficient progress had to abandon the work, which was completed by the Railway Company itself.

The cost of the finished tunnel was 2,786,700 Fr. ($537,833), or about 784 Fr. per meter ($46.10 per ft.).

5. **The Jungfrau Railway Tunnel.** (No. 10 of Table A and No. 5 of Table B.)

The railway, which proposes boldly to reach the peak of the Jungfrau, 4166 m. (13,668 ft.) high, the famous summit of the Bernese Alps, is now built and opened for operation with a total length of 9474 m. (31,083 ft.) to the station of Jungfraujoch at an elevation of 3457 m. (11,342 ft.). At this point the work has been provisionally stopped. From Km. 2.163 (1.34 mi.), where the road traverses the solid rock of the Eiger to the present terminus—that is to say, at 7113 m. (23,337 ft.)—the road lies in a tunnel, which winds in curves with a least radius of 167 m. (548 ft.) near the surface of points between stations, windows cut through the rock can be reached by means of short cross-drifts.

The tunnel was constructed in four sections from 1897

to 1912. The survey inside the tunnel was based on topographical and photogrammetrical measurements of the mountain.

As the longitudinal profile indicates, the grade in the stations was 3 to 11%; for a stretch of about 3 km. (1.9 mi.) between Eismeer and Jungfrau-joch 6.33%, and for the remainder 25%.

The working was driven as a top heading and worked from the under side only. It was then immediately widened to full section in the arch and the side stopes removed. The tunnel lies for its entire length in unusually hard rock, the lower 5 km. (3.1 mi.) in Alpine limestone and the upper part in gneiss. On that account it was possible to do away with not only the timbering of the heading but also the masonry lining of the tunnel.

The theoretical excavated profile measured 3.7 m. (12.14 ft.) wide, 4.05 m. (13.29 ft.) high above the top of the ties with a cross-section area of 14.6 sq. m. (157.1 sq. ft.) and a depth of ballast of 0.30 meters (0.98 ft.).

The actual cross-section proved to be larger than the theoretical in consequence of the greater amount of rock which had to be removed during the first years. Also the niche, 0.70 m. x 0.85 m. (2.3 x 2.79 ft.), which was blasted out from Km. 2.20 to 3.80 (1.37 to 2.36 mi.) at the spring-line level, and intended for carrying the high-pressure current, crumbled slowly away, so that the unprotected conductor, carrying a 7000-volt current, had to be replaced in a short time by a cable.

The drilling was done as far as the station of Eismeer by electrical drills, at first by those of the Union Electrical Co. of Berlin, according to the Marvin system, and then by Siemens & Halske crank-percussion drills. Two of the latter machines did as much as four of the Marvin system machines. The Siemens & Halske machine used, moreover, only 1.50 hp., while the Union machine used 5 hp. On the other hand, the cost for repairs of the former was 100% higher than for the latter. From Eismeer on, compressed-air drills, Ingersoll system, were used; also percussion drills of the Flottmann system subsequent to the year 1910 were occasionally employed. The freezing of the air conduit was prevented by the installation of a condensed-water receptacle.

The average monthly progress in the heading reached 115.2 m. (378 ft.); in the lower side stopes, about 115.00 m. (377 ft.); the highest daily progress was 4.80 m. (15.7 ft.).

A single blast in the heading gave about 0.85 m. (2.79 ft.) progress on an average; in the lower side stopes, about 1.40 m. (4.59 ft.).

Dynamite and Westfalite were used for blasting. One running meter of the tunnel fully excavated required about 40 kg. (26.8 lbs. per ft.) of blasting powder, 65 m. of fuse and 35 firing caps (65 ft. of fuse and 11 firing caps per ft.). In the beginning, especially during the winter months, frequent accidents resulted from frozen dynamite. Thereupon the manufacturers produced a special brand of ''not easy to freeze'' dynamite, and such accidents were thus prevented.

Various ventilators, which delivered the air at the headings, were used for the ventilation of the tunnel. Inasmuch as the higher one went, the less oxygen there was, the bad effects of the gases due to dynamiting made themselves felt by the workmen sooner and much more noticeably than in the valley. Owing to insufficient ventilation, symptoms of carbon monoxide poisoning frequently appeared among the workmen, such as headache and complete loss of consciousness. On that account an oxygen inhaling apparatus was kept in the workings. The diameter of the ventilating pipe was 400 mm. Three ventilators were put into the air pipe at about 1 km. (0.6 mi.) apart. The temperature in the tunnel ranged from + 7° C in the upper part to — 3.0° C.

It might be mentioned, as a most extraordinary event, that on Sunday, the 15th of November, 1908, in the storeroom at Km. 3.600 (2.23 mi.) the whole winter's supply of dynamite, about 25,000 kg. (55,120 lbs.) exploded. The cause of this accident is yet unknown. The partition wall at the tunnel bore, about 20 m. (65.6 ft.) thick and for a distance of about 40 m. (131 ft.) was seriously damaged. Fortunately there was no further accident.

According to the accounts of the Company, the cost of the tunnel, without the lateral widening for the stations, was:

For the stretch—	Length m*	Elevation m*	Fr.†	Per running m. Fr.
Scheidegg-Rotstock	759 (672+87‡)	2100-2500	466,559	614
Rotstock-Eigerwand	1510	2500-2900	995,030	659
Eigerwand-Eismeer	1296	2900-3200	1,286,480	993
Eismeer-Jungfrau-joch	3635	3200-3500	4,126,204	1135
Total	7200	2100-3500	6,874,273	955

Notwithstanding the experience gained during the years and the introduction of improvements in the operation of construction, there was a heavy advance in the unit costs of the tunnel for the step 3200-3500 m. elevation (10,500-11,480 ft.) compared to that from 2100-2500 m. elevation (6890-8200 ft.). Difficult conditions affecting work, transportation and rock formation are considered the principal factors occasioning this astonishing difference.

6. The Lötschberg Tunnel. (No. 6 of Table B.)

After a new connection with Italy had been assured for West Switzerland and the country lying behind it, by means of the Simplon Tunnel between the Mt. Cenis and St. Gotthard Tunnels, the canton of Bern aspired to get for itself and that area lying to the northwest and traversed by French, English and Belgian railways, a direct line to the Simplon and the upper part of the Canton of Wallis. After careful examination of various competitive plans, the line through the "Lötschberg" was chosen.

The enterprise was financed in 1906 by the Bern-Alpine Railway Company, Bern-Lötschberg-Simplon, on the basis of a forfeiture contract entered into with a French firm of contractors. The line was to be built with a maximum grade of 2.7% and a least radius of curvature of 300 m. (984 ft.). It was to be operated by electricity, with a 15,000-volt single-phase alternating current of 15 cycles. The total cost of construction was estimated at 83,000,000 Fr. ($16,019,000). The most important part of the work, which lay between the sta-

* 1 meter = 3.28 ft. † 1 franc = $0.193.

‡ Small tunnel between Scheidegg and Eigergletscher.

tions Kandersteg on the north and Goppenstein on the south, was the Lötschberg Tunnel. This tunnel, about 13,800 m. (45,275 ft.) long, single track with a turn-out in the middle, was undertaken by a syndicate of contractors for the lump sum of 37,000,000 Fr. ($7,141,000). The Canton of Bern shared the cost of construction by assuming a subsidy in the sum of 17,500,000 Fr. ($3,377,500). The Swiss Confederation, for its part, made an additional grant of 6,000,000 Fr. ($1,158,000) in order that the large tunnel might be double-tracked from the beginning and that both approach slopes might be prepared for double-tracking later. The total cost of the tunnel was increased to 50,000,000 Fr. ($9,650,000) owing to the double tracking.

Immediately after the signing of the contract, in July, 1906, the work of surveying was begun. The tunnel was laid out on a tangent, with the exception of a curve 93 m. (305 ft.) long and with a radius of 400 meters (1312 ft.) at the south approach. The Kandersteg and Goppenstein axis points were connected to each other by a simple triangulation with the geodetic triangulation of the III order of the Bernese Oberland. In this way a sufficiently accurate survey was made over the mountain, taking into consideration the deviation of the plumb line, and which permitted the tunnel alignment to be given on each side by a sight to a signal point through tipping of the telescope. The determination of the elevation of both axis points was accomplished by tying in to government precision levels. The longitudinal profile given in the accompanying table shows that the north portal was 1199.9 m. (3937 ft.), the summit 1242.7 m. (4077 ft.) and the south portal 1219.45 m. (4001 ft.) elevation, and that the grade on the north side was 0.7 and 0.3% and on the south side, 0.38 and 0.245%. The maximum clear opening of the double-track tunnel is 8.00 m. in width, 6 m. in greatest height (26.2 ft. x 19.7 ft.), and has a cross-section of 40.7 sq. meters (438.1 sq. ft.). The conduit [60 x 60 cm. (23.6 x 23.6 in.) with 0.7% grade], can drain off 730 sec-liters of water (25.8 sec.-ft.).

The installations included, on both sides, the plant for the operation of the drills and ventilators, setting-up and maintenance of the machinery, tools and transportation material;

lodging for the officials and men; and welfare equipment such as baths, showers, dry and disinfecting rooms, hospitals and schools.

Meyer's compressed-air percussion drills were used on the north side; on the south side, the Ingersoll drills. Two 2-stage compressors of about 350 hp. each furnished the necessary air at 10 atmospheres pressure. For ventilating purposes there were two Capell centrifugal blowers of 60 cubic meters (2118.9 cu. ft.) per minute capacity each, at a pressure of 250 mm. (9.84 in.) of water. The furnishing of fresh air to the workings was gradually improved in 1909 and 1910 by the installation of two powerful Capell fans of 25 cubic meters (882.9 cu. ft.) per second capacity each, at 250 mm. (9.84 in.) of water pressure, each requiring 160 hp. There was built in the finished tunnel an air duct of 6.4 sq. meters (68.89 sq. ft.) cross-section through one of the masonry partition walls, at the end of which secondary ventilation, consisting of turbo-blowers, injectors and sprays of water, was installed, in order to bring fresh air—0.5 to 1.0 cubic meters (17.65 to 35.3 cu. ft.) per second—to the face of the workings. After holing through, the secondary ventilation was discontinued, the wall broken down, and the ventilation carried on, partly by blowing, partly by suction through the full tunnel section.

Transportation in the tunnel was provided by means of compressed air locomotives, for which 2 Meyer's and 2 Ingersoll compressors of 220 hp. each furnished air at 120 atmospheres. The gage of the "dinky" was 0.75 m. (2.46 ft.).

The entire plant was operated by electricity. The electric energy, about 400 hp. at first and reaching 2500 hp. in the four working years, was furnished by the railway company from the power plants of the United Kander and Hagneck Works as a three-phase 15,000-volt alternating current. The electric stations contained all the necessary means for transforming and distributing the current. For this the contractors had to pay a sum of one million Fr. ($193,000) for each end of the tunnel.

The complete excavation was accomplished from a bottom heading of 6 sq. meters (64.6 sq. ft.) cross-section, through top drifts or uprisers according to the character of the rock.

According to the opinion of the geological experts, the tun-

nel, after traversing in its northern third the talus lying on the slope of the mountain, should pass through Cretaceous and Jurassic sedimentary deposits. The Gastern granite and crystalline slate comprised the other two-thirds. In the Gastern Valley, which was crossed at a depth of 180 m. (590 ft.) beneath the floor of the valley, the tunnel must certainly have had not less than 100 m. (328 ft.) of solid rock above it. Another opinion, to which little attention was paid, advocated the digging of a test shaft over the tunnel center in the Gastern Valley for the purpose of obtaining some light on this last question.

Drilling began in October, 1906, with hand tools; machine drilling began on the north side on the 7th of March and on the south side on the 9th of April, 1907. Four and one half years after the beginning of the machine drilling, that is, on the 9th of September, 1911, the tunnel, according to contract, was to be completed. The average daily progress reached a maximum in the limestone of the north side in June, 1908, of 7.57 m. (24.8 ft.), in the gneiss of the south side in August, 1908, with 6.10 meters (20 ft.). In the second quarter of 1908, on the north side the daily number of rounds* was 6; on the south side, 5. There were required per cubic meter of excavation in the bottom heading in the high mountain limestone of the north side in the second quarter of 1908, 2.44 m. (6.12 ft. per cu. yd.) drillhole, 3.76 kg. (6.33 lbs. per cu. yd.) dynamite and an equivalent of 2.42 m. (6.06 ft. per cu. yd.) drill steel. Each drill cut 117 meters (384 ft.) of hole before repairs were necessary. Per cubic meter of the remaining excavation, 0.50 kg. of dynamite was used (0.85 lbs. per cu. yd.), or an average for the whole excavation of 1.13 kg. (1.91 lbs. per cu. yd.) was required. The crystalline schist and gneiss of the south side required at the end of 1908, 2.63 m. (6.61 ft. per cu. yd.) of drill hole, 4.16 kg. (7.02 lb. per cu. yd.) of dynamite and 4.64 m. (11.6 ft. per cu. yd.) of drill steel per cubic meter excavated. Each drill made 1 meter (3.28 ft.) of hole in 0.37 of an hour and after boring 29 meters (95 ft.) of hole had to be repaired. For widening to the full section, which was done in part by boring drill, in part by percussion drill and in part by hand,

*Round-drilling holes, backing away and shooting.

1.32 kg. (2.23 lbs. per cu. yd.) of dynamite was used, or an average for the whole excavation of 1.70 kg. per cubic meter (2.88 lbs. per cu. yd.). In the Gastern granite section in the middle of the tunnel the quantity of dynamite used and the wear and tear on the drills was somewhat higher.

Two unfortunate events occasioned considerable delay in the driving of the headings in 1908.

On the 29th of February, Goppenstein, the southern power and service site, was partially destroyed by an avalanche, and the hotel belonging to the company destroyed, whereby twelve people lost their lives. As a result of this occurrence, operations were suspended on the south side during the month of March. This was followed on the north side on the 24th of July, at Km. 2.675, under the Kander River in the Gastern Valley, by a breaking in of water and earth. Within ten minutes about 7000 cubic meters (247,200 cu. ft.) of material and 2400 cubic meters (84,700 cu. ft.) of water rushed into the heading and filled it almost entirely for a length of 1175 meters (3854 ft.). The 25 workmen in the heading were not able to escape in time and perished. The cave-in spread up to the surface of the valley, where an elliptical depression of 40 by 50 m. (131 ft. x 164 ft.) diameter, and a maximum depth of 2.10 m. (6.9 ft.) appeared. There could be no doubt about it: the workings, contrary to the geological predictions, had left the solid rock lying on the right side of the valley slope and had run into the alluvial deposits of the Gastern Valley saturated with the ground-water of the Kander. The destroyed headings were for the time being abandoned, and closed at Km. 1.426 (0.88 mi.). The water escaped by means of seven pipes. The discharge of water decreased from an original 4000 to 95 second-liters (141 to 3.3 sec-ft.).

Negotiations between the railway company and the contractors as to the continuing of the work, resulted with the consent of the Swiss Ry. Department, in abandoning the continuation of the tunnel in a straight line and in moving the crossing up the valley, in an easterly direction, where the granite remained in the floor of the valley.

The relocated tunnel bends at Km. 1.203 (0.75 mi.) from the north portal, with a curve of 1100 meters (3609 ft.) radius,

from the straight line location towards the left and returns to the same (straight line location) after describing two wide curves of the same radius as above at Km. 3.998 (2.48 mi.) from the south portal. The new heading begins at Km. 1.368 (0.85 mi.) so that the length of the abandoned portion amounted to 1307 meters (4287 ft.). The length of the relocated section is 9330 meters (30,610 ft.), of which 2237 meters (7338 ft.) are curved. The greatest deviation of the new location from the old is 1610 meters (5281 ft.). This necessitated an increased length of 810 meters (2658 ft.).

Only in February, 1909, the work of driving could be taken up again. The daily progress increased amazingly. The average daily progress on the north side reached a maximum in July, 1909—in Alpine limestone using 4 Meyer percussion drills—of 10.66 meters (34.97 ft.). In January, 1911, in the Gastern granite with 5 machines a maximum of 8.24 meters (27.03 ft.) was attained. On the south side, in March, 1911, using 5 Ingersoll machines, a maximum of 6.55 meters (21.49 ft.) was obtained. The greatest daily headway was 13.2 meters (43.31 ft.) in the limestone and 10.6 meters (34.77 ft.) in granite.

The rock temperature reached a maximum of 34.0° C at a point 6.150 km. (3.82 mi.) from the south portal. The greatest depth of rock over the tunnel, about 1570 meters (5151 ft.), was at Km. 6.250 (3.88 mi.) from the south portal.

The holing through occurred on March 31, 1911, at 7.353 km. (4.57 mi.) from the north portal. The check measurement showed a lateral deviation of 257 mm. (10.1 in.) 102 mm. (4 in.) in the elevation and, relatively to the calculation, a decrease in length of 0.41 meter (1.35 ft.) in a total length of tunnel of 14.612 km. (9.08 mi.).

The lining of the tunnel could not keep pace with the rapid progress of the headings, because the ventilation left much to be desired until the holing through occurred. The masonry lining consisted principally of a thin facing, which was partly composed of artificial stone of a least compressive strength of 180 kg. per sq. cm. (2560 lbs. per sq. in.) after 28 days. An invert was constructed for only 426 meters (1398 ft.).

In 1911 the water carried away by the conduit varied between 60 and 566 liter-seconds (2.1 to 20 sec-ft.).

The composition of the mortar employed is especially to be

noted. In two factories especially constructed for the purpose, Portland cement was mixed with stone dust in varying degree and formed into "Lötschit". "Lötschit 10", or that mixture having a tensile strength of 10 kg. per sq. cm. (142 lbs. per sq. in.) was used instead of hydraulic lime; "Lötschit 22", or that having a tensile strength of 22 kg. per sq. cm. (312.9 lbs. per sq. in.) was used instead of pure Portland cement. The Swiss test called for a minimum tensile strength of 6 kg. per sq. cm. (85.3 lbs. per sq. in.) for hydraulic lime and 22 kg. per sq. cm. (312.9 lbs. per sq. in.) for Portland cement, all after 28 days. Good lime and cement always give a considerable excess strength over the requirements.

There was used on an average per cubic meter of masonry lining 120 to 150 kg. (202 to 253 lbs. per cu. yd.) of mortar. The lining was completed on the 22nd of April, 1912. This made 7.3 meters (23.95 ft.) of completed tunnel per day.

The total excavation was 843,034 cubic meters (1,102,190 cu yds.), the masonry 190,098 cubic meters (248,535 cu. yds.), and 4,046,543 days' work were consumed. There were 64 fatalities.

By postal order, 8,480,148 Fr. ($16,366,685) were sent to Italy.

The railway was opened on the 15th of June, 1913.

A suit is still pending between the Railway Company and the contractors arising out of the catastrophe of July 24th, 1908. Disregarding this suit, the cost of the tunnel was stated as 50,071,000 Fr. ($9,663,700), or 3427 Fr. per meter ($201.65 per ft.).

7. The Tasna Tunnel. (No. 7 of Table B.)

The Tasna Tunnel, 2350 meters (7710 ft.) long, lies on the Lower Engadine Bevers-Schuls line of the narrow-gage Rhaetian railway, between the stations of Ardez and Fetan. It is a side slope tunnel, made necessary by an extensive slide of the sides of the ravines in the valley of the Inn River between the valleys of Tasna and Püzza.

The tunnel penetrates the slope in the Tasna Valley in a northerly direction in order to reach hard rock as soon as possible, turns in a curve of 200 m. (656 ft.) radius towards the east and then runs in a straight line 2118 meters (6949 ft.) to the eastern portal in the Püzza Valley.

The longitudinal profile shows the tunnel as running from the entrance on the Ardez side for 300 m. (984 ft.) up with a grade of 0.2% to the summit, 1385 m. (4544 ft.) elevation, whereupon a down grade of 2% occurs to the portal on the Fetan side. The maximum grade on the open line is 2.5%.

The survey of the axis was done by means of a triangulation connected with both ends of the tunnel, the base line of which was connected with a base measured at Tarasp in the Inn Valley.

The tunnel lies for about 300 meters (984 ft.) in broken granite, then for a short space in serpentine, and for the most of its length in Bündner schist, which is intersected by veins of gypsum. On account of the weakness of the rock, and with an eye to economy, hand drills were used exclusively. On that account the plant was reduced merely to the installation of the absolutely necessary shacks and storehouses. An electric cableway connected the principal working headquarters at the entrance to the headings with the valley road, some 100 meters (328 ft.) below. The air was renewed in the tunnel by ventilators at each end.

The drilling began on the Fetan side in December, 1908; a year later on the Ardez side.

The order of operations was as follows:

From the tunnel entrance (on the Ardez side) as far as Km. 1.50 (0.93 mi.), the Belgian system was employed; that is, top-heading, excavation of the arch, lining of the arch, invert cut, complete excavation and building of masonry side walls.

For the lower half, the work was carried out according to the "full excavation" method, that is, bottom heading, top cut, excavation of the arch, excavation of side stopes, and masonry lining of the walls and arch.

The heading had an average height of 2.2 meters (7.22 ft.) and a breadth of 2.5 meters (8.20 ft.) and a cross-section of 5.5 sq. meters (59.2 sq. ft.), and required timbering for practically half its length.

The tunnel is lined throughout with ashlar set in Portland cement, and for about 1500 meters (4920 ft.) with a strengthened pressure section, in part even as thick as 1 meter (3.28 ft.).

During the night of the 16th and 17th of June, 1910, at Km. 0.200 (0.12 mi.) from the Ardez portal, a cave-in occurred in the heading, accompanied by a great inflow of water. Owing to this the driving of the heading on this side was discontinued for a full seven months and the holing through delayed at least three months.

The holing through occurred on the 7th of July, 1912, with a very exact meeting of the axes; the masonry was finished by the end of April, 1913. This showed an average daily progress in the headings of 1.84 meters (6.03 ft.) and a progress of 1.50 m. (4.92 ft.) of finished tunnel.

The number of days' work consumed was 257,109. Blasting powder was used as follows: For the headings, 26,700 kg. (58,740 lbs.) of dynamite; for the widening out 30,600 kg. (67,320 lbs.) of Westfalite, Telsite and Cheddite; 8,142,000 firing caps and 185,000 meters (606,900 ft.) of fuse.

This gives unit amounts as follows:

	Blasting Powder	Firing Caps	Fuse
Per running meter in tunnel..	24.4 kg. (16.36 lbs. per ft.)	3465 (1056 per ft.)	78 m. (78 ft. per ft.)
Per cu. m. of excavation	0.8 kg. (1.35 lbs. per cu. yd.)	115 (88 per cu. yd.)	2.5 m. (6.28 ft. per cu. yd.)

There were seven fatalities.

The final figures are withheld, but the cost of the tunnel itself should be 1,592,000 Fr. ($307,256) or about 678 Fr. per meter ($39.86 per ft.).

The opening of the Lower Engadine line, Bevers-Schuls, occurred on the 1st of July, 1913, according to program.

8. The Mt. d'Or Tunnel. (No. 1 of Table C.)

Instigated by a spirit of competition to have the best connection between Paris and Milan, the Paris-Lyon and Mediterranean Railway Company of France determined to improve their approach to the Simplon Tunnel by means of a double-track cut-off from the station of Frasne to the Swiss border railway station of Vallorbe. The actual distance between Paris and Milan was shortened 17 km. (10.56 mi.) by a line 25 km. (15.53 mi.) long, the maximum grade on the French side was lowered from 2.5% to 1.5% and the summit of the line was

lowered to 900.19 m. (2953.37 ft.) elevation, or about 115 meters (377 ft.). The line cuts through the Jura range of the Mont d'Or, 483 m. (1584 ft.) below the highest elevation, by a tunnel 6097 m. (20,003 ft.) long of which 989 m. (3244 ft.) lie in Swiss territory. The maximum grade on the Swiss approach was 2.0%. The tunnel has a grade of 1.3%, entirely on the Vallorbe side, on a tangent of 5404 meters (17,730 ft.) and a 1.09% grade on an approach curve of 700 m. (2296 ft.) radius. This condition necessitated the principal part of the work being done from the Vallorbe end. Four compressors were installed here requiring an aggregate of 940 hp. These delivered the air for the drills at 8 atmospheres. There were also three compressors of 220 hp. each for the operation of 7 compressed-air locomotives which required 150 atmospheres. For ventilation, 2 Sulzer ventilators of 50 hp. each were set up outside the tunnel, three similar machines on the inside.

For drilling in the heading on the north side, Meyer's percussion or rotating drills were used, depending upon the nature of the rock. Of the latter there were four on a drill carriage with a cross shaft. For the widening out, percussion drills only were used.

The plant installed on the Frasne side was simpler: one 200-kw. transformer, one 210-hp. electric motor, one Ingersoll-Rand compressor for the operation of the percussion drills, one portable engine of 120 hp., with generator attached for reserve, one Farcot ventilator of 42 hp. for the ventilation, four electric pumps of 25 liter-seconds (0.88 sec-ft.) capacity for handling the water from the neighboring slopes, and three gasoline locomotives for the tunnel service.

The gage of the temporary tracks on the Swiss side was 1.00 m. (3.28 ft.); on the French side, 0.60 m. (1.97 ft.).

The electric energy for the operation of the installations at either side of the tunnel was furnished from the power house of the "Power Co. of Lake Joux" in the form of a three-phase current of 13,500 volts. Baths, hospitals and schools were established.

The tunnel axis was determined by a triangulation and a direct survey over the mountain.

The driving of the bottom heading began on the 14th of

November, 1910, on the Vallorbe side, at first with a cross-section of 7 sq. meters (75.35 sq. ft.), and later 9 sq. meters (96.88 sq. ft.); excavation and top heading followed. As soon as the arch was excavated, the arch masonry lining was laid up on iron centers, then the sides stoped out and masonry lining of side walls laid up. On the Frasne side only a top heading was used; in other respects the work was carried on in the same manner as on the Vallorbe side.

On the latter side 6 set-ups were made, in three daily shifts, of 12 to 20 drill holes each 1.50 meters (4.92 ft.) deep, each hole loaded with from 2 to 3 kg. (4.4 to 6.6 lbs.) of dynamite (blasting gelatine of 93% nitroglycerine). As an example, in September, 1912, the average daily headway was 8.20 meters (26.90 ft.).

At first about 1 km. (0.62 mi.) of dry lime rock was traversed; then 3.2 km. (2.0 mi.) of blue, impervious lime, for about 800 m. (2625 ft.), interspersed with marl, which swelled up and dissolved in water. After the marl, fissured limestone was encountered. In this formation on the 23rd of December, 1912, at Km. 4.273 (2.65 mi.) from the Vallorbe portal, 93 meters (305 ft.) behind the face of the heading, large quantities of water were struck, amounting to 3000 liter-seconds (106 sec-ft.). During the hasty flight from the tunnel, two work trains collided, but the whole affair fortunately came out without loss of life. The discharge of water sank to 700 liter-seconds (24.7 sec-ft.) on the 25th of December, but increased again to 5000 liter-seconds (175.5 sec-ft.) on December 28th and 29th on account of rain and melted snow, and after about 14 days remained steady at from 350 to 400 liter-seconds (12.3 to 14.1 sec-ft.). The water pouring out of the tunnel caused considerable damage on its way to the Orbe. Owing to this, the springs of the streamlet "Bief Rouge", 5 km. (3.1 mi.) distant and lying 84 m. (275 ft.) above the tunnel, dried up. This entailed serious hardship on the part of those having water rights further down the stream.

The heading was closed by means of a wall 7 meters (22.9 ft.) thick; two pipes with manometers and valves were installed to regulate and shut the flow of water off completely. On Jan. 17, 1913, the valves were closed and on the 19th to the

23rd of the same month the springs of the "Bief Rouge" began to flow again. Under the protection of the dam the tunnel canal was built for carrying off 1000 liter-seconds (35.3 sec-ft.) of water and a conduit was installed outside the tunnel with a capacity of 7000 liter-seconds (247 sec-ft.). The water dammed up behind the wall was released from the 21st to the 24th of February, 1913, the barricade itself was then removed and the driving of the heading resumed. But the "Bief Rouge" disappeared again. On the 17th of April, 1913, at Km. 4.407 (2.74 mi.), another spring was run into, which flowed into the heading with great violence and made it necessary to evacuate. Continuous rains and copious melting snow caused the water to increase during the following night to nearly 10,000 liter-seconds (353 sec-ft.), which, nevertheless, was carried away without any serious damage. Simultaneously the water veins which had been encountered earlier dried up, which was an indication that the different pockets were connected with each other and with the entire spring region of "Bief Rouge". By means of a parallel heading the locations where water appeared were passed around; the holing through of the heading was accomplished on October 2, 1913, at Km. 5.044 (3.13 mi.) from the Vallorbe portal. The work had consumed in all 1054 days and showed an average daily progress of 5.79 meters (18.99 ft.). The maximum daily progress on one side was 11.00 meters (36.1 ft.) in the Oxford strata.

The tunnel had to be lined with masonry for its whole length, provided with an invert, and in stretches made water-tight with cement grout. Owing to the outbreak of the war the work suffered a serious set-back. In the spring of 1915, they first succeeded by means of an ingenious system of drains to make the masonry water-tight where the springs had been found and to place the veins and pockets under a pressure of 84 meters (275.6 ft.) of water, so that the flow again started in "Bief Rouge".

There were eleven fatalities during the construction of the tunnel.

The cost of construction, although the completed figures have not yet been given out, has been stated at about 21,000,000 Fr. ($4,053,000) or 3444 Fr. per meter ($202.65 per ft.).

The opening of the Frasne-Vallorbe line occurred on the 16th of May, 1915. No artificial ventilation has been provided for. It is hoped that the natural draft of the tunnel, with its unilateral ascent of about 78 m. (256 ft.), will always be sufficient to remove the smoke and to renew the air.

9. The Hauenstein Base Tunnel. (No. 2 of Table C.)

In order to improve the northern approach to the Gotthard on the Basel-Olten route, the Confederation in 1910 granted a credit of 24,000,000 Fr. ($4,632,000) for the construction of a cut-off line with base tunnel through the Hauenstein. At the present time, the Jura range is pierced by the oldest of the great Swiss tunnels built during the last 60 years, namely, the Hauenstein Tunnel, 2495 m. (8186 ft.) long. The construction of this tunnel lasted from 1854 to 1857 and was accompanied by a bad fire and cave-in, in which 63 men lost their lives. The summit of the existing line is at Läufelfingen station, 561.80 m. (1843 ft.) elevation. The north approach has a maximum grade of 2.13%; the southern, in the tunnel, a maximum grade of 2.626%. The new line branches from the old line at Sissach station, reaches the north portal of the Base tunnel, 8134 m. (26,686 ft.) long, immediately behind Tecknau station, with a maximum grade of 1.05%. After leaving the tunnel it crosses the Aare, in order to reach the station of Olten, one of the principal junction points of the Swiss Railway System. The northern leg of the tunnel is 1807 m. (5928 ft.) long and has a 0.15% up-grade; the southern leg is 6327 meters (20,758 ft.) long and has a down-grade of 0.5% and 0.75%, approaching Olten. The summit lies at an elevation of 451.73 meters (1482.1 ft.), that is 110 meters (360.8 ft.) below the highest point of the existing line. The new line is to be 111 meters (364.1 ft.) effectively, but 30 km. (18.6 mi.) virtually shorter than the old. The running time for passenger trains will be shortened from 15 to 20 minutes, for freight trains 25 minutes.

In January, 1912, the work was let, after twice submitting to bids, and at an increase of price of about 13%. The total cost of the new line will amount to about 26,000,000 Fr. ($5,018,-000) on this basis. According to the figures of the Federal Railways, the reduction in annual expense through a saving

in personnel and material should represent a capital of 27,500,-000 Fr. ($5,307,500).

The determination of the direction and elevation of the two-track straight-line tunnel was made by means of a triangulation and set of levels tied in with the Swiss general survey. For control, a direct survey of the axis was made over the mountain. On the 20th of February, 1912, the driving of the heading was begun with hand drills, on the south side at Olten.

In the course of the year, the construction of the plants on both sides was completed. The work tracks had a gage of 0.75 m. (2.46 ft.). In the reinforced-concrete power house on the south side, which on account of the longitudinal profile had to undertake the larger part of the work, two Sulzer Diesel motors, connected on the same shaft, delivered 500 hp.; also three low-pressure compressors, each requiring 225 hp., furnished each about 30 cubic meters of air per minute at a pressure of 8 atmospheres. A conduit system of patent welded pipes of 200 mm. diameter (7.9 in.), carried the air to the various workings, where, in heading 2 to 3, in the widening, 30 to 35 percussion drills were in operation. Outside, the transportation was done by means of steam locomotives. Inside the tunnel, compressed-air locomotives of 9.5 to 24 tons service weight were used. Two high-pressure compressors, of 250 hp. each, furnished 13 cubic meters of air (459.1 cu. ft.) per minute each at 150 atmospheres for the operation of the tunnel locomotives, which had a working pressure of 135 atmospheres. Three Sulzer No. 9 high-pressure ventilators arranged in series and requiring about 50 hp. each, furnished 5 cubic meters of air per second each, with a pressure of 500 to 600 mm. of water. These were put in successively, following the driving of the heading, so that at the end of the conduit they always had at their disposal 5 cubic meters (176.6 cu. ft.) of air per second. The air ducts were made of sheet metal, 3 mm. thick and 1000, 800 and 500 mm. diameter (0.1181 in. thick and 39.37, 31.50 and 19.68 in. diameter).

There were in addition installed on the south side a steam-driven saw mill; an electric lighting plant of 110 hp.; an elec-

trically-operated pump for furnishing 80 liter-seconds (2.8 sec-ft.) of clear water for the Diesel motors and compressors; blacksmith shops and repair shops, with all the necessary machines and tools; a magazine for the storage of 10,000 kg. (22,000 lbs.) of dynamite; baths; medical and sanitary quarters; quarters for the officials and men; the necessary buildings for the administration and inspection departments; and a telephone plant and installation furnishing connection between all these buildings and the tunnel. Because there was less work on the north side, the plant was correspondingly smaller, although similar. After the plant was finally set up, the work went on at a rapid and smooth pace. The headings traversed the different marl, gypsum, anhydrite, dolomite, muschelkalk, oolite and Bajocian strata of the Jura range. The rock was for almost the entire length stable and for the most part dry. The greatest amount of water encountered was 119 liter-seconds (4.2 sec-ft.) on the south side and 11 liter-seconds (0.39 sec-ft.) on the north side. The temperature reached a maximum of 25° C. at a point of maximum overlay 482 meters (1581 ft.) below the surface.

From the bottom heading, excavation was carried on by means of a top heading, later, by means of a top cut enlargement to full arch-section and the removal of side stopes. The masonry of the side walls and arch followed at a short distance.

The holing through occurred on the 10th of July, 1914, 18 months before the stipulated time, at 5.865 km. (3.64 mi.) from the south portal. This showed a daily average progress of 9.35 meters (30.68 ft.) since the beginning of the tunneling. The greatest daily headway yet made was 16.3 meters (53.47 ft.) in March, 1913, on the north side.

The control of the axis showed a lateral deviation of 4.5 mm. (0.17 in.), a deviation of 12 mm. (0.47 in.) in the elevation, and a difference from the computed length of —1.20 m. (3.94 ft.).

The masonry lining, for the most part a thin facing, was laid in cement mortar throughout. In the stretches that were dry and not subject to pressure, an artificial stone was used for the arch with a specified minimum crushing strength of 180

kg. per sq. cm. (2560 lbs. per sq. in.) but having in fact an average crushing strength approaching 300 kg. per sq. cm. (4267 lbs. per sq. in.).

At the beginning of August, 1914, owing to the war, the work had to be considerably reduced. In spite of everything, the arch was completed on the 9th of April, 1915. An average daily progress of 7.12 m. (23.36 ft.) finished tunnel was made.

To the 31st of March, 1915, 1,236,959 days' work were required in the tunnel and for the plant installed outside and connected with it. Work was interrupted on account of a strike from the 8th to the 18th of July, 1912. There were 9 fatalities.

The cost of the tunnel to sub-grade, exclusive of the ventilating system, was estimated on the basis of the contract at 18,563,000 Fr. ($3,582,660) or 2282 Fr. per meter ($134.28 per ft.).

The stretch between Tecknau and Olten, 11 km. (6.83 mi.) long, is divided into two blocks by a block station in the tunnel, 4434 m. (14,548 ft.) from the north portal. The greatest possible safety is secured for a following train by means of double forward signals of three lights each, electric back signals, warnings released by rail contact and axle counters electrically connected with the contact fingers of the block signal. In order to facilitate the re-starting of trains which have been stopped by the block signals, the grade was reduced for a stretch of 500 m. (1640 ft.) from 0.75% to 0.5%. For ventilation during operation a circular shaft 5.6 m. (18.4 ft.) diameter and 133 m. (436.3 ft.) deep was sunk in the valley of Zeglingen, 3593 m. (11,787 ft.) from the north portal, just beside the tunnel, and connected with this station. The natural draught of the shaft has to be increased when necessary by two centrifugal exhaust ventilators, electrically operated, placed at the upper mouth. The cost of the shaft alone is estimated at 170,000 Fr. ($32,810); that of the total ventilating system at 265,000 Fr. ($51,145). It is estimated that the necessary power for operation will not exceed 180 hp.

The cut-off line is to be opened on the 1st of January, 1916.

10. The Grenchenberg Tunnel. (No. 3 of Table C.)

In order to improve the northern approach to the Bern-Lötschberg-Simplon Line the Bern-Alpine Railway Company built a connecting road about 13 km. (8.07 mi.) long, between the Federal Railway stations Moutier and Lengnau. By this means the distance of 40 km. (24.85 mi.) between the important junction points of Moutier and Biel was to be shortened 16 km. (9.94 mi.) and the summit of the line crossing the Jura made 227 m. (744.7 ft.) lower.

The most difficult construction connected with the new line was the Grenchenberg Tunnel, which traverses between the stations of Moutier and Grenchen, the limestone formation of the Graitery and Grenchenberg mountain chains of the Jura and the Tertiary valley Chaluet lying between them. The greatest overlay above the tunnel was 876 m. (2874 ft.). The tunnel is 8565 m. (28,100 ft.) long, single track, and on a tangent except for one curve 55 m. (180.4 ft.) long and 300 m. (984 ft.) radius on the north opening. With a maximum grade of 1.5% in the open line, the longitudinal profile of the tunnel shows from north to south for 3900 m. (12,795 ft.) a grade of 0.25% up to the summit, which is at an elevation of 545 m. (1788 ft.), and from that point a slope on a 1.3% grade for 4665 m. (15,305 ft.). The net cross-section was 25.5 sq. meters (274.4 sq. ft.).

The location of the axis was determined by means of a tying in to a government triangulation, elevation was obtained by means of connection with the government precision levels and controlled by a survey over both the mountain chains.

Excavation was carried on from the bottom heading by a top cut, in bad rock by a top heading, enlargement to full arch section and removal of side stopes.

For drilling in the bottom heading, four Meyer air-pressure percussion drills were used on a drill carriage; for the complete excavation percussion drills, and in the soft molasse, spiral hand drills were used. In the tunnel, transportation was handled by means of air locomotives, and outside by steam locomotives, both of 75 cm. (29.5 in.) gage. The necessary compressors for the drills (Meyer, 10 atmospheres) and locomotives (Ingersoll, 100-120 atmospheres) were provided at the plants installed at either end of the tunnel.

The motive power, consisting of an alternating current of 16,000 volts, was distributed to the work by suitable transformers.

Meyer turbo-ventilators of a maximum capacity of about 3 cubic meters (105.9 cu. ft.) per second served to ventilate the tunnel and carried fresh air by means of conduits 600 mm. (23.62 in.) in diameter.

An aerial cableway for bringing stone from a quarry 2 km. (1.24 mi.) distant, work shops, magazines, office buildings, and different workingmen's welfare institutions, such as barracks, baths, washrooms, hospitals and schools, completed the equipment.

Work was started the beginning of November, 1911, and in October, 1913, on the north side, a daily average progress was reached of 9.74 m. (31.9 ft.), and a very nearly similar average on the south side. Two and seven-tenths kg. per cubic m. (4.55 lbs. per cu. yd.) of blasting powder (Telsit) were used on an average in the bottom heading, and for the total excavation, an average of 0.7 kg. per cubic m. (1.18 lb. per cu. yd.).

The highest temperature reached was 20° C. The tunnel was masonry lined for its whole length; the least thickness was 35 cm. (13.78 in.); the thickness as a rule shown in the pressure profile was 2.00 m. (6.56 ft.) in the walls and 0.70 m. (2.3 ft.) of hewn stone in the invert. In the sound rock, economizing arches of 4.5 m. (14.8 ft.) span and 2.5 m. (8.2 ft.) width of pier were used. For the arch there was used as follows: in the sound rock, artificial stone blocks 25 by 12 by 6 cm. (9.84 x 4.72 x 2.36 in.), with a guaranteed minimum compressive strength of 230 kg. per sq. cm. (3270 lbs. per sq. in.), laid in slag cement having a compressive strength of 210 kg. per sq. cm. (2987 lbs. per sq. in.) in stretches where there was pressure, cut stone laid in Portland-cement mortar of 380 kg. per sq. cm. (5405 lbs. per sq. in.) compressive strength was used—these compressive strengths to be shown after 28 days.

Throughout the marl stretches an invert 30 to 50 cm. (11.8 to 19.7 in.) thick of Portland cement with filling concrete of slag cement was laid. In the wet stretches the arch was covered with a layer of cement mortar 5 cm. (1.97 in.) thick, a coat of

asphalt 5 to 7 mm. (0.2 to 0.275 in.) thick and a 6 cm. (2.36 in.) protecting coat of lime sandstone set in mortar.

Owing to strikes, earth pressure, inflow of water and military mobilization, the work exceeded the stipulated time about four months. Notwithstanding, the bottom heading was holed through October 27th, 1914, showing a daily progress of 7.9 m. (25. 9 ft.) on the average. Alignment and elevation were good. A check survey has not yet been made.

At the end of March, 1915, the total excavation amounted to 338,436 cubic m. (442,674 cu. yds.), the masonry to 93,204 cubic m. (121,910 cu. yds.), and 1,261,731 days' work had been required. There were six fatalities.

The completion of the tunnel took place on July 24, 1915, and the opening of the line on October 1, 1915.

Among the difficulties encountered, the inbreaks of water are particularly notable. These occurred from February to May, 1913, between Km. 1.300 (0.81 mi.) and 1.700 (1.05 mi.) from the south portal, after the heading passed through the Tertiary molasse into the Jura chalk. There was also encountered on the 7th of February, at Km. 1.488 (0.92 mi.) a water vein discharging about 50 liter-seconds (1.75 sec-ft.); at the same time the spring which supplied water for 18 water-power plants and furnished drinking water for the community began to fail and on the 4th of March it stopped flowing entirely.

Next in Sequan formation a pocket was encountered at Km. 1.615 (1.0 mi.), which reached with many ramifications about 20 m. (65.6 ft.) to the right and 70 m. (229.6 ft.) to the left of the railway axis and about 40 m. (131.2 ft.) above the invert. The water flowing from the tunnel reached 830 liter-seconds (29.3 sec-ft.) and slowly decreased to 500 (17.7 sec-ft.). On the north side there appeared springs of 30 to 300 liter-seconds (1 to 10 sec-ft.) in the Varian and principal oolite strata and the total water decreased here in June, 1913, to 215 liter-seconds (7.6 sec-ft.). A pumping plant had to be installed to supply the drinking water, by which means the practically pure water from the tunnel was conducted to the existing distributing system. The water power works had to be operated by electricity and the owners indemnified.

The cost of the tunnel complete, without the ventilating system will probably be 17,500,000 Fr. ($3,377,300), or 2043 Fr. per meter ($120.20 per ft.).

Ventilation during operation is to be carried out by the same system employed in the Simplon and Lötschberg tunnels with a shield.

A twin ventilator operated by an electric motor of 70 hp. will force 75 cubic meters per second of air with a pressure of 30 mm. (1.18 in.) of water into the tunnel, so that a wind velocity of 3 meters (9.8 ft.) per second will be reached. The shield will be connected with the signals and will be moved by an electric motor of 15 hp.

MISCELLANY.

A. Legal Enactments.

According to Article 26 of the Statutes of the Swiss Confederation, legislation regarding the building and operation of railways lies in the power of the Federal authorities.

Accordingly, Article 14 of the Statutes concerning the building and operation of railways, of December 25, 1872, provides that the general and detailed plans of a proposed railway shall be submitted to the Federal Council for ratification. The power of ratification of the Federal Council is vested in the Railway Department.

Article 9 of the Statutes concerning the Building and Operation of Swiss Secondary Railways, of March 10, 1906, provides concerning tunnels of Secondary Railways as follows:

(1) Tunnels according to Art. 4 must have a clear profile on curves with a least clearance of 0.20 meter (0.66 ft.); that is, considering the elevation of the outer rail, the width of the gage and the extreme projections on the middle and outer side of the cars.

(2) Niches must be provided on both sides at uniform intervals on each side of not more than 50 meters (164 ft.).

The dimensions of the cross-section in the plans submitted for ratification for Principal Railway tunnels are established by act of the Government. Hence, provisions are made for each case as it comes up with regard to the style and manner of construction of the masonry, the quality of the mortar, the thick-

ness of the arch, etc. In the same manner, the type of masonry to be chosen for any particular locality is subject to the approval of the Board of Supervision.

The Federal Railways are compelled by law, the Private Railways by the decree of Concession, to provide for the shutting down of the work on Sunday, except in the face of the headings and where work is urgent.

In special cases, for the defense of the country, the installation of mine chambers is required by the Federal Council. In new concessions for railways these mine chambers are to be installed at the expense of the railway company. For the rest, the management is given a free hand in the choice of the type of construction. In the construction of the larger tunnels, a report as to the progress of the work is demanded at stated intervals. An engineer from the Railway Department is charged with the control of the construction according to the plans.

B. Conclusions of the International Railway Congress at Bern, 1910.

Apropos of Question 4, of the International Railway Congress held at Bern, in July, 1910, concerning the construction, ventilation, and the operation of long railway tunnels, notable reports regarding mountain and Alpine tunnels were presented by Mr. Canat, Chief Engineer of the P. L. M., Paris, Dr. Hennings, Professor in the Polytechnic School at Zürich and Rudulf Heine, Chief Engineer in the Royal and Imperial Railway Bureau at Wien. The various questions are there dealt with in a distinguished and exhaustive manner and we take the liberty of referring to this work. They are discussed in detail in Section I and by vote of the meeting the following conclusions were adopted:

1. For long mountain tunnels, particularly those of 5 km. (3.1 mi.) upwards, double-track construction was recommended.

The locating heading should be driven as a bottom heading.

The use of a top cut instead of a separate top heading appears worthy of commendation, but it requires further investigation.

In rock subject to pressure the cross-section of the tunnel should approach as nearly as possible a circular form. For making the tunnel water-tight, spraying with cement grout could be used with great success; but it was recommended that a more economical way be found.

2. Machine drilling should be extended to all parts of tunnel construction as far as conditions permit.

3. In tunnel construction mechanical traction is to be generally introduced; nevertheless, steam engines must be unconditionally excluded from the workings.

4. Mechanical mucking in the locating heading has not led to a final decision and has to be studied further.

5. Good ventilation in places where construction is going on is an indispensable requirement. For the longer tunnels an air supply of 3 to 6 cubic meters (106 to 212 cu. ft.) per second should be furnished. With regard to very long tunnels with a very high temperature, it would appear that a lower heading as a ventilating conduit would prove a beneficial method of construction.

6. It is necessary to provide for good artificial ventilation in tunnels now in operation that have not sufficient natural ventilation. Artificial ventilation increases the safety of operation of the tunnel and in a great degree is an aid to better preservation of the superstructure.

As the descriptions of the separate construction work have shown, the experience obtained in the long Swiss tunnels built since 1910 confirms these principles in general. We might, however, supplement them by the following remarks:

1a. Distinguished experts have expressed themselves in favor of the double-tunnel method of construction instead of the two-track method, and, without a doubt, the fortunate completion of the Simplon tunnels is due to this method of construction. Notwithstanding this, the double-tunnel system has not been chosen for any of the tunnels undertaken during the last ten years. From an operative standpoint, the two-track tunnel is superior to the two single-track tunnels.

The use of a top cut has shown itself advantageous in connection with the new system and is used wherever the nature of the rock permits.

Double-track tunnels having a maximum width of 8 m. (26.24 ft.)—such as the Gotthard and the Lötschberg—present, in the case of trains to be operated by electricity, difficulties for the practical installation of the conductors and contacts. The maximum width should be not less than 8.4 m. (27.5 ft.).

In regard to the fashioning of the masonry section, it is necessary to take into consideration recent experience and observations concerning rock pressure and stability.

2a. In spite of its many undisputed good qualities, the Brandt hydraulic drill has not been used since the construction of the Simplon tunnels. The remarkable progress in the driving of the headings in the Lötschberg and Hauenstein tunnels was achieved with compressed-air drills (rotary and percussion) irrespective of their use in granite, gneiss, or limestone of varying hardness. The percussion drills were also adaptable for drilling operations at all places where construction was in progress outside the headings. Electric drilling on the Jungfrau Railway was also displaced by air drills, because the compressed air assisted in the ventilation and the air drills needed less repair than those electrically driven.

3a. For transportation inside of the tunnel, compressed-air locomotives were used exclusively for new construction.

4a. The important question of shortening the time consumed in mucking, has lost its significance in those instances where the use of percussion drills is possible in driving the headings, since the set-up of the drills, carried by hand, does not depend on the removal of all the loosened rock.

5a. Neither the side heading proposed by Engineer Chiapuzzi nor the under heading recommended by the Railway Congress has been effectively employed in the prosecution of a Swiss tunnel. The practicability of this method is seriously contested. The temporary dividing off of a portion of the finished tunnel measuring about 6 sq. meters (64.58 sq. ft.) by means of a light, tight wall and the use of the resulting conduit for the flow of fresh air, presents an easy and practical means for ventilation during construction. That this system did not afford entirely satisfactory ventilation in the various localities of the Lötschberg tunnel was due, not to any fault in the system, but to the circumstance that in this tunnel the masonry lining was

far behind the driving of the heading and the principal and secondary ventilators provided insufficient service during considerable periods of time.

6a. The ventilating system known as "Saccardo", used many times in Italy and Austria, and for example in the United States in the Alleghany Tunnel of the Virginia Railroad, has an advantage in that it leaves the tunnel free from any permanent fittings. It requires, however, a very great consumption of power and entails a corresponding high cost of operation. Since its installation in the Gotthard Tunnel it has not been in further use in Switzerland, but has been replaced in the Simplon, Lötschberg and Grenchenberg tunnels by the Sulzer-Locher system with the movable shield, which, if not simpler, is at least considerably cheaper to operate. Simple and cheap to operate is the ventilating shaft, with ventilators, installed in the Hauenstein Base-Tunnel, and copied after the Severn Tunnels of the English Great Western Railway. Unfortunately, its use is limited to the especially favorable topographical conditions of the overlay.

With reference to the deterioration of the rails, observations at the Simplon, Gotthard and old Hauenstein tunnels have shown that neither electric action nor any special chemical composition of the water, with special reference to its content of sulphates or chlorides, is responsible for the more or less serious deterioration of the superstructure. On the other hand, the rapidly progressing deterioration of the rails and fastenings, especially in the wet places, is increased in great degree by the warm air of the tunnel. In deep tunnels, careful drainage, water-tightness of the arch and copious ventilation are absolutely necessary for an economical and safe maintenance of the tracks.

C. Organization and Cost of Construction.

The average daily progress in tunnels built during the last ten years shows a considerable advance in the driving of the headings as well as in the masonry lining. Besides the improvements in mechanical arrangements and the method of construction, this is principally due to the perfection of the organization of the entire construction work. One may well say that, in this connection, the regulations of the now deceased Colonel Ed. Locher, at the time of the construction of the

Simplon tunnels, are typical. Not to underestimate possible difficulties and to leave nothing to chance that may be foreseen are the axioms of all good organization, and also guarantee success in tunnel construction. To accomplish this the following are principally necessary:

(1) Careful preparation of all work, also in relation to geological and geodetic conditions.

(2) Plentiful equipment of the outside plants, especially in arrangements for drilling, ventilation, and cooling when necessary.

(3) Rigid discipline in the use of blasting powder.

(4) The greatest order in carrying on the transportation in and outside of the tunnel.

(5) Minute caution in carrying on the work when encountering pressure or water-carrying rock.

(6) Greatest possible avoidance of lost time between the different kinds of work.

(7) Thorough-going arrangements for the health and welfare of the workmen.

(8) Sharp supervision of the work in detail and as a whole.

(9) Choice of the best qualified people for the management of the various types of work and the pitiless removal of unfit persons.

(10) Use of the latest advancements of science and technique in every sphere of engineering construction.

Some of these rules lie at the bottom of the epoch-making "scientific management" of F. W. Taylor, now deceased, and there can be no doubt that the conscious and consistent use of the Taylor System in the construction of tunnels will, in many cases, present great possibilities of improvement.

Consideration of the above requirements results not only in shortening the time required for construction and in decreasing the cost, but also in lessening the sacrifice of human lives, which unfortunately cannot be entirely avoided even in the prosecution of works of peace.

The following small tabulation gives comparative figures for some of the larger Swiss tunnels:

Tunnel	Track	Length m. (A)	Constructed During Years	Av. Daily Progress Headings m. (A)	Av. Daily Progress In Tunnel m. (A)	Average No. shifts per day during construction	Total No. Fatalities In total	Total No. Fatalities Per Km. (B)	Cost of Actual Tunnel In total Fr. (C)	Cost of Actual Tunnel Per m. Fr. (C)
Gotthard	2	14,998	1872-81	5.47	4.45	2480	177	11.8	58,513,154	3907
Simplon Tunnel I	1	19,803	1898-05	8.25	7.51	2676	51	2.57	58,500,000*	2954*
Ricken	1	8,603	1904-10	5.39	3.53	617	17	1.97	12,867,000	1495
Lötschberg	2	14,612	1906-12	8.98	7.30	2467	64	4.38	50,071,000	3427
Grenchenberg	1	8,565	1911-15	7.90	(§)	1016‡	6‡	0.70‡	17,500,000†	2043†
Hauenstein Base-tunnel	2	8,134	1912-15	9.35	7.12	1086	9	1.15	18,563,000	2283*

* Inclusive of bottom heading II. ‡ Figured up to the 31st of March, 1915.
† Still in course of construction. § Not yet figured up.
(A) 1 meter = 3.28 ft. (B) 1 km. = .621 mi. (C) 1 Fr. = $0.193.

As regards the costs of construction they are found—aside from accidents such as inflow of water, pressure stretches, etc.—to depend in large degree on the rate of wages paid. These have risen steadily in the last decade. For an eight-hour working day, wages were paid as follows:

	In the Gotthard T. 1880 Fr.†	In the Simplon T. I 1908 Fr.	In the Lötschberg T. 1910 Fr.	In the Hauenstein T. 1913-14 Fr.
Miners	4.40-4.80	5.50*	5.00*	6.10
Carpenters	5.20-5.60	5.50*	5.80*	6.50
Train men	3.40-3.80	4.20*	4.50*	5.10
Masons	5.20-5.75	5.15	6.20*	6.70

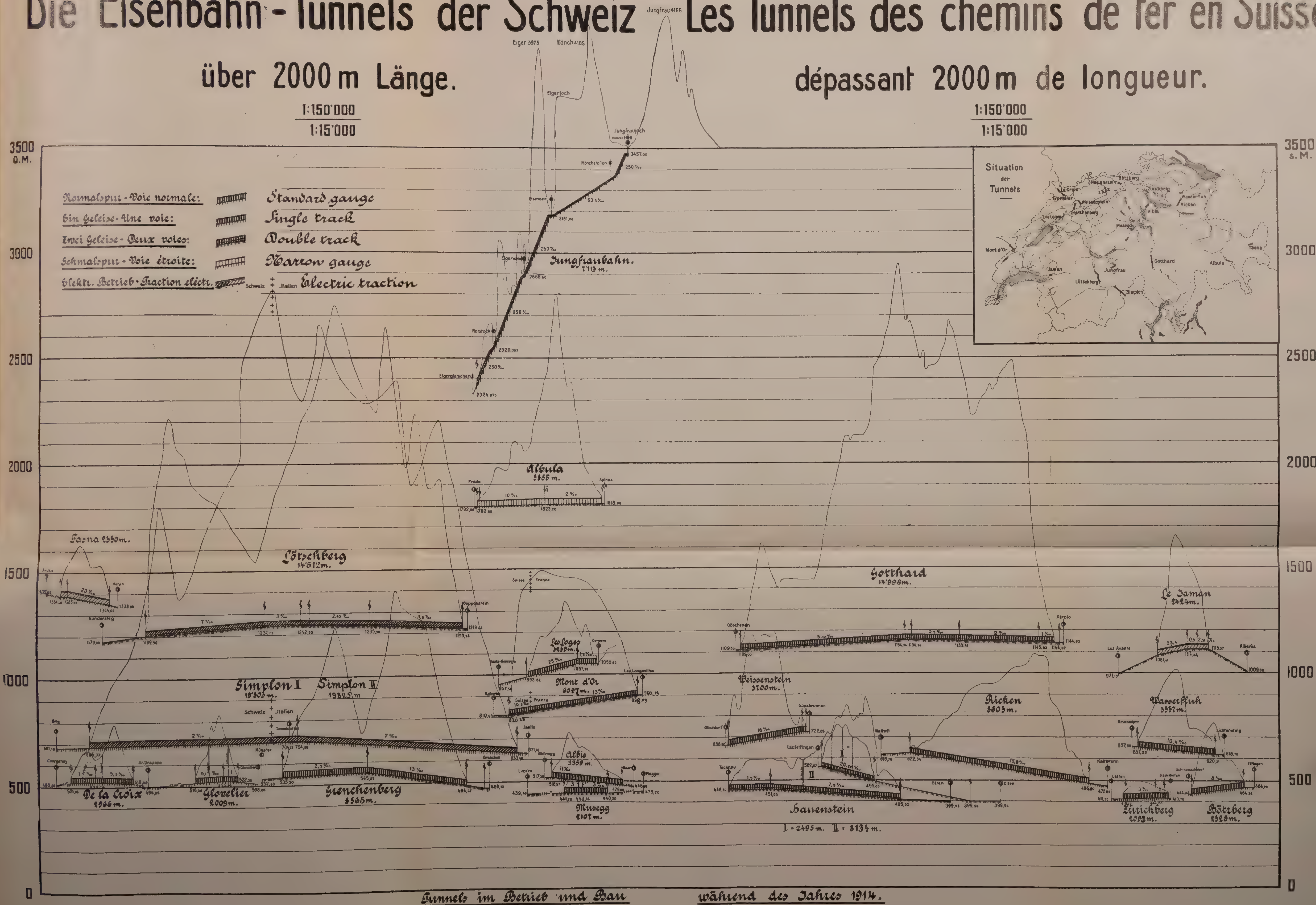
That the cost of the finished tunnel has not increased in a like degree is due to the above mentioned improvements in the management of the construction work by which the interest on the investment and the costs of general administration have been decreased. Finally, one should be very cautious in making a critical comparison of the cost of construction from figures in

* Average.
† 1 franc = $0.193.

The Swiss Railway Tunnels more than 2000 m in length.

Die Eisenbahn-Tunnels der Schweiz über 2000 m Länge.

Les Tunnels des chemins de fer en Suisse dépassant 2000 m de longueur.



Tunnels beeing worked and built during 1914.

different publications, as they often rest upon quite different bases. In the preceding, the cost is only for what is known as the actual cost of construction, and therefore without interest, general administration, ballast, super-structure, telegraph, signals and all arrangements for the operation of the electric trains.

CONCLUSION.

The construction of a long tunnel is an undertaking which, more than any other, involves the entire field of engineering in its relations to the branches of modern science. Geology and geodosy, with all their sister sciences, physics, chemistry, statics and dynamics, hydraulics, electricity, political economy and law, government and hygiene, the proper care of sickness and accidents as well as the entire technology of the constructions of machinery and of building materials must be drawn upon in order to prepare and carry out such an undertaking.

Fire and water, gases and rock pressure have opposed engineers in their struggle to break through the mountains new paths that should unite nations. But the spirit and strength of the men grew with the magnitude of the obstacles; and thanks to the tools which science and experience have placed at their disposal, they have finally come out of the battle victorious.

Although the tasks of the engineers undertaken and brought to a successful termination in Switzerland cannot compare with the gigantic proportions of the piercing of the Isthmus of Panama, still they have this in common with the brilliantly conducted work of Col. Goethals and his staff, that they constitute a triumph of the human spirit and of the organizing genius of their leaders.

And even if the harvest of these mighty creations on both sides of the Atlantic Ocean is delayed on account of the most horrible war that history has ever known, we will not relinquish the hope that a day will yet dawn when the frightful wounds inflicted by this bloody struggle on body and property will heal, and the nations of the earth again pass in friendly competition over the paths which have been prepared for them from land to land and from ocean to ocean.

In concluding I must not neglect to thank those gentlemen

who have assisted me with needed information, and in the most courteous manner, in the preparation of this report. They are Messrs. Vogt, Chief Engineer of the General Management and Grünhut, Chief Engineer of the Third District of the Swiss Federal Railways; Custer, Chief Engineer of the Bern-Alpine Railway; Liechty, Director of Operations of the Jungfrau Railway; Luder, Chief Engineer of the Solothurn-Münster Railway; Nivert, Chief Engineer of the P. L. M. Co.; Schucan, Chairman of the Board of Directors, and G. Zollinger, Section Engineer of the Rhaetian Railway, and my co-workers in the Swiss Railway Department.

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Paper No. 86

AMERICAN RAILROAD BRIDGES.

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INTRODUCTORY.

American railroad bridges as now constructed are the results of an evolution, during the course of which many types found to be undesirable were abandoned; some types found to be good were maintained and new features and types were introduced, until, finally, the 1915 standards represent the culmination, at the end of more than three-quarters of a century of railroad bridge history. During the first period, extending to 1865, there was no real science of proportioning members and the best that builders could do was to be guided by judgment based on experiment or precedent, and to make all new bridges stronger than before. During the second period, 1865 to 1890, scientific designing became general and the typical American railroad bridge, "a skeleton structure pin-connected at all the principal articulations," was brought to a fair state of development. The present standards were essentially developed during the third period, 1890 to 1915. As the past history and the status at the end of the second period (1890) has been recorded[1], the scope of the present sketch will be confined to the third period, ending in 1915, and will embrace an outline of the effects of some of the important influences on the development; a discussion of the characteristics of the present standards and tendencies; and an illustration of features which may be considered typical of the best American practice.

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[1] "American Railroad Bridges", by Theodore Cooper, Transactions American Society of Civil Engineers, Vol. XXI, 1889.

INFLUENCES ON THE DEVELOPMENT.

Naturally, the trend of improvements in bridge construction has been controlled by a number of definite influences, some of which are still in operation, and will undoubtedly continue long into the future. American railroad bridges, therefore, although substantial, economical and durable, are still in a state of development, the final culmination of which cannot as yet be foretold. The most persistent of these influences has been the constantly increasing weight of rolling loads. For instance, the heaviest engine in operation on the Baltimore & Ohio Railroad in 1865 weighed 91,000 lbs. (41,314 kg.) ; in 1890, the heaviest engine weighed 133,000 lbs. (50,382 kg.), an increase of 46% in the twenty-five years; at the present time, 1915, the heaviest engine on this road weighs 463,000 lbs. (210,203 kg.), an increase of 247% during the past twenty-five years. Most of the other railroads have had similar experience, and in some instances the increase has been even greater. It has far exceeded anything which was anticipated in the past, and has been the direct cause of the renewal of many bridges which would have been still serviceable under the loads for which they were designed. Perhaps it would have been better engineering if the builders of these bridges had possessed the foresight necessary to anticipate the extent and the effects of these increases, but, unfortunately, engineers are not endowed with occult powers; and the fact remains, that while they always built their structures strong enough to carry some increase in loading, the rapidity and extent of this increase, heretofore, were neither fully appreciated nor anticipated. Locomotives are now so heavy, and take up so much space in length, width and height, that it is no longer impossible to anticipate the limit and to make ample provision therefor.

All of the earlier types of patented bridges were tested in service to the full extent of their capacity and endurance and it was observed that while they were good enough for the light loads and traffic of their day, their flimsiness, due to the inherent defects of their designs, and their action under traffic made them very unsatisfactory structures for heavier loads. They, therefore, became obsolete and were replaced by the improved types of single-intersection, pin-connected trusses, and by riveted, lattice and plate girders, which were evidently much superior

and which had been developed to such a state of perfection by the year 1890 that engineers believed they had established standards of design which would endure. These more modern bridges have also been tested in service under increasing loads to the full extent of their capacity, as was the case with the earlier bridges, and it has been learned that, while these later bridges were also well adapted to the traffic of their day, their designs embodied features and details which prevented them giving long and satisfactory service under the heavier loads which were constantly being placed upon them. The trusses had too many adjustable members and light bars to shake loose, too many hinged joints to wear away, and too much motion of parts to inspire confidence under the fast speed of heavy engines and trains. The necessity for less looseness and greater stiffness became apparent, and it was found that when the flimsy, adjustable bracing was replaced with stiff bracing with riveted connections, and the shaky eye-bars were tied together so as to reduce motion, the stiffened structure gave much more satisfactory service. Therefore, the effects of the influence of the constantly increasing loads on railroad bridge development is evidenced by the elimination of adjustable members and short span trusses, and by the general stability and solidity of construction which are the essential characteristics of present standards.

Another influence in American bridge development has been the introduction of new materials of construction. In the old abandoned types, wrought iron rods or links were used generally for tension, and wood or cast iron for compression members. The substitution of wrought iron for the cast iron and wood enabled the construction of the improved types which were standard in 1890, and which had details and connections far superior to anything which could be obtained by the use of cast iron or wood. Since 1890, rolled structural steel has entirely supplanted wrought iron in metal bridge work, and on account of its greater strength and economy it has had an influence on the construction of longer lengths of spans, both in girders and in trusses, than were attempted with wrought iron. The standard structural steel, at the present time, has an ultimate strength averaging about 60,000 lbs. (27,240 kg.); and the longest simple span so far constructed of it is 620 ft. (189.1 m.). This span is in the

Kentucky and Indiana Terminal Railroad Company's bridge across the Ohio River at Louisville, built in 1912.

Alloys and special steels, with much greater strength than standard structural steel, are now used in long span trusses for the purpose of keeping the dimensions and weights of members within the limits of commercial and economical production. For instance, nickel steel was used in the construction of 668-ft. (203.7 m.) spans of the Municipal Bridge at St. Louis, built in 1912. Nickel steel eye-bars and so-called silicon steel compression members will be used in the Ohio River Bridge at Metropolis, the longest span being 725 ft. (221.1 m.); high carbon steel is being used in the 977.5-ft. (298.1 m.) span of the Hell Gate Bridge; and Mayarí steel, which contains nickel, and is made from the Mayarí ore from the north coast of Cuba, is being used in the construction of a large bridge which is to span the Mississippi River at Memphis. These alloys and special steels have not, as yet, exerted any material influence on the development of railroad bridges, except, perhaps, in the direction of greater span lengths than can be economically, or even practically, constructed of the standard structural steel.

A material which has come into general use during the past few years is reinforced concrete. It has had a very decided effect on bridge development, since it has influenced the adoption of a new type of short-span bridge having a ballasted deck and a solidity of construction with an economy impossible to be obtained by the use of any other available material.

Another influence on bridge development is the improvement in tools and machinery, especially in pneumatic tools and self-propelling erection derricks. Pneumatic drills, reamers and riveters are now generally used in erection work in place of the old-time hand tools, and as a consequence, field-riveted connections are no longer avoided, as was the case in 1890, since they can now be easily and quickly made. By the use of self-propelling erecting derricks, plate girders and bridge members of a weight far beyond what was formerly practicable can now be handled and erected with safety, facility and economy.

While there are some other influences which have had an effect on American railroad bridge development, it will be seen that those mentioned, viz., increasing rolling loads, introduction

of new materials, and improvements in tools and machinery, encouraged development always in the direction of greater stability and solidity of construction. They indicated the essential requirements and the means for accomplishment. And, while engineers have now established generally recognized standards of good practice and have developed what are considered permanent structures, admirably adapted to existing conditions, it remains for the future to determine whether or not these standards will endure.

PRESENT STANDARDS AND TENDENCIES.

The development of American railroad bridges did not take place spasmodically, with long intermissions of inactivity, but was a gradual process, requiring rather a long time to establish characteristics which could be considered decided improvements on what had preceded. These distinctive features have, heretofore, become clearly defined at the ends of twenty-five-year periods. Therefore, in order to accentuate the effects of the various influences which have been working and to define the present status of bridge development in a comprehensible manner, the main characteristics which were prominent at the beginning of the third period will be described, for the purpose of comparison with the dominating characteristics of the standards at the end of this period.

At the beginning of the period (1890), pile and framed timber trestles were being constructed on main lines. Plate I. The design differed in no material respect from the earliest types, except as to number and dimensions of timbers, the floor deck being composed of cross-ties resting on groups of timber joists. In suitable locations, they were economical, easy to maintain under their light traffic and regarded as all-sufficient for the purpose. Howe truss bridges were also being built on main lines of some roads. They gave good service and were amply strong for the traffic of their day, could be constructed expeditiously by the railroad company's forces, and be maintained in good condition on about the interest of the cost of an iron bridge. On other roads, combination bridges, with all the tension members of wrought iron, and all, or most, of the compression members

of wood, were used. They were cheaper than all-iron bridges, and more durable than Howe trusses.

I-beam bridges composed of groups of from two to four beams under each rail, the beams being held together by means of cast iron separators bolted between the webs, and with cross-ties resting directly on the upper flanges of the beams, were commonly used for spans having a length of from 10 to 20 ft. (3.05 to 6.1 m.). Plate I. Plate girders were acceptable for spans up to 65 ft. (19.8 m.), which was about the limit for economical construction and handling, although some few roads constructed girders of a greater length. Single or double intersection riveted low truss bridges, or latticed girders, as they were called, were used for spans between 65 ft. (19.8 m.) and 100 ft. (30.5 m.), and in some cases up to 120 ft. (36.6 m.); but the longer spans were not acceptable to many engineers on account of the inability to ship the trusses in one piece and the necessity of so much field riveting of important connections, and the increased risks and cost of erection. For spans over 100 ft. (30.5 m.) the practice, with very few exceptions, was to construct trusses of the pin-connected type. Plates II and IV. This typical American railroad bridge, as defined by Mr. Theodore Cooper[2], was a skeleton structure, pin-connected at all the principal articulations; its principal characteristics, in addition to the pin-connections, being the minimum ambiguity of strains, the concentration of parts, facility of manufacture, perfection of length and fitting of all the members, a minimum of riveting and mechanical work in the field, and the readiness with which the individual members can be assembled during erection. Typical American railway viaducts[3], with 30 ft. (9.15 m.) towers and 30 ft. (9.15 m.) or 60 ft. (18.3 m.) free spans were regarded favorably. Movable bridges were of the swing type, revolving in a horizontal plane on a center pier. Plate VII. Lateral bracing for truss bridges, viaducts and in many through plate girders had adjustable rods for the tension members and the counters in truss bridges were also made adjustable. Wrought iron was still used for built-up

[2] "American Railroad Bridges", by Theodore Cooper, Transactions American Society of Civil Engineers, Vol. XXI, 1889.

[3] "The American Railroad Viaduct", by J. E. Greiner, Transactions American Society of Civil Engineers, Vol. XXV.

members, but eye-bars and wide web-plates of girders were generally made of soft steel.

Bridge piers and abutments were generally of cut stone masonry construction, and arches were of cut stone work throughout or had their rings made of brickwork. The arch was then recognized (as it is now) as the very best type of railroad bridge, but cut stone work was very expensive in first cost as compared with steel, and as a consequence relatively few arch bridges were being built. Plates II and XII.

Nearly every railroad in America constructed its bridges in accordance with specifications peculiar to the individual road; consequently, there were practically as many kinds of bridge specifications as there were important railroads. The makers desired to be thought original, and therefore displayed their ingenuity in those parts of bridge specifications that gave them the most leeway, viz., in the permissible working stresses, column formulas, grades of steel, impacts and in the typical engines used as a basis for proportioning. In these numerous specifications every conceivable kind of typical locomotives was specified, some with practically the same total weight, but with a different distribution of loads on the wheels and a different wheel spacing. There were no generally recognized standards for loading, impact allowances, permissible working stresses, or for the quality of material used and methods of testing same. Contracts were based on a total price for the completed work, and as the total price depended largely on the amount of material which entered into the construction, successful competition frequently depended upon a design which gave the lightest possible structure.

At the close of this period (1915) open deck framed timber trestles are seldom built except on light traffic or branch lines or as temporary expedients, with the expectation of replacing them with permanent structures in a short time. In many sections good timbers can no longer be obtained except at excessive cost; the general upkeep is expensive and they are an undesirable type for heavy loading. Some roads now build wooden trestles of a different type, inasmuch as they have ballasted decks on solid timber flooring and are constructed of creosoted timbers. Plate I. These modern types are more durable and easier to maintain than the old open-deck structures and represent the best practice

for timber trestle construction, but they cannot as yet be considered as general standards. Some western railroads are replacing timber trestles with a type made of reinforced concrete with ballasted decks. Plates I and XIV. This is a distinctive type as compared with the trestles of 1890. Howe truss bridges and combination bridges are no longer constructed, except in very isolated cases or on unimportant branches. They are ill-suited for heavy loading and good timbers are difficult to obtain.

I-beam bridges as now constructed are generally encased in concrete. Plate I. Open decks with wooden cross-ties are avoided, stone ballast on concrete being used as a substitute; and on some roads short spans are reinforced concrete girders or slabs. Plate girders are being built and shipped in one piece in spans up to 120 ft. (36.6 m.), and, in some cases, of even longer length; the ability of the railroad companies which handle them being still the governing condition. Shipping conditions require a limit in the depth of these girders to about 10 ft. (3.05 m.), and for this depth they are now more economical than riveted trusses of the same depth for spans between 100 ft. (30.5 m.) and 120 ft. (36.6 m.). The standard practice in regard to riveted trusses is to use them for spans between 120 ft. (36.6 m.) and 200 ft. (61. m.), although much longer spans are built. Plate III. The pin-connected truss bridges may still be considered typical of American practice, but only for spans greater than 200 ft. (61.0 m.). Plate V. Many of the characteristics which were so favorable to the construction of this type in 1890 are no longer peculiar to it, since the improvements in tools and machinery and in methods of handling and doing the work now enable the construction of riveted bridges having practically all the good characteristics of pin-connected structures, with the exception of the number of rivets, and this is no longer an objectionable feature. Riveted trusses have the additional favorable characteristic in the harmonious working of the various sections and parts of members, a condition which is not always obtained in the pin-connected type. The superiority of the riveted truss, which for a long time has been recognized in Europe, is now quite generally conceded by American railway bridge engineers, except for spans of such lengths as to require riveted connections to be too cumber-

some for practical and effective construction. The typical American railway viaduct, with its steel towers, is still considered a good type when all bracing is stiff (Plate VI); but concrete piers, in a number of cases, have been constructed in preference to the steel towers, since they are less expensive to maintain, and, in favorable locations, are not much more expensive in first cost. Plate XV.

Swing bridges, revolving in a horizontal plane, are still being constructed (Plate VIII); but there are several patented types of bascule bridges, revolving in vertical planes, which in recent years have been exploited by commercial agents to such an extent that there are a number of them now being built in places where the swing bridge would have been just as adaptable and far more economical, and where there is no apparent reason for their construction, aside from their novelty and the impressions of the arguments which the patentee's agents have had on the minds of the bridge engineers who recommend their use. There are, of course, locations where navigation interests practically require the construction of this type of movable bridge, but as a general rule they are unsightly and uneconomical as compared with a properly constructed swing bridge. Another recent type of movable bridge is hauled up and down with wire ropes and counterbalanced by masses of concrete suspended over the tracks from steel cables. These are special types designed to compete with bascule bridges, and there are some locations and conditions which are particularly favorable to their construction. While a number of these types have been constructed, they are special types and are not in what can be called general use. Plates IX, X and XI.

All lateral bracing is now made of stiff members with riveted connections. Adjustable members, even for counters, are preferably avoided; and metal bridges are made entirely of steel, wrought iron having for a number of years past been an uncommercial product for bridge construction. Open decks, with cross-ties resting directly on top flanges of beams or girders, while still used to a considerable extent, are undesirable for short spans under the present heavy traffic; the preference being for a solid ballasted deck, so as to maintain a continuous ballasted road bed. Plate I.

Monolithic concrete masonry with a few rods imbedded for tying the mass has practically replaced cut stone work for piers and abutments; and reinforced concrete arches are replacing short span steel bridges and stone arches, since the cost of this type of bridge, in locations suitable for its construction, is but little more than the cost of a steel bridge with a solid floor, and in many cases the cost may be even less. They can be easily and expeditiously constructed, even under traffic, and are very substantial; but whether or not these reinforced concrete arches will be as durable as cut stone work is a question for the future to decide. Plates III, V and XIII.

In 1894 Mr. Theodore Cooper suggested a standard typical loading designed to meet all the various requirements at that time, but arranged in such a manner that the stresses produced by this loading would be directly proportional to the weights of engines. This suggested loading consisted of two consolidation engines, with their tenders, coupled together and followed by a train load reduced to an equivalent uniform load in pounds per lin. ft. The different loadings were designated as E-25, E-30, E-35, E-40, etc.,[4] the numerals representing the weights in thousand pounds on each driver axle. The weight on the forward truck of the locomotive was 50%, that on each tender axle 65% and the uniform train load 10% of the weight on one driver axle. The wheel spacing was the same for each class of loading, regardless of the weight. This loading, on account of its simplicity, has now become a general standard.

At the beginning of the third period, wrought iron plates and shapes were commercial products and were largely used in bridge work, steel being considered less reliable and less economical on account of special workmanship required, except for eyebars and for long span structures. A few years later, when commercial structural steel had entirely replaced wrought iron, there were two grades in general use; one known as soft steel, with an ultimate strength of from 52,000 lbs. to 60,000 lbs.; and the other as medium steel, ranging from 60,000 lbs. to 68,000 lbs. The medium steel when used was proportioned for a 10% higher working stress than that permitted for soft steel. The manufac-

[4] "Train Loading for Railroad Bridges", by Theodore Cooper, Transactions American Society of Civil Engineers, Vol. XXXI, 1894.

turers gave bridge engineers precisely the same steel, whether they specified soft or medium, the soft being rolled near its upper limit and the medium near its lower limit. The author in 1901 specified only one grade, viz., 60,000-lb. steel with a variation of 5000 lb. each way.[5] This grade of steel is now the general standard in railroad bridge construction. In 1903 the American Railway Engineering Association adopted general specifications for steel railway bridges covering loads, impacts, unit stresses for proportioning parts, details and quality of material[6]; and this was the first successful attempt at the standardization of American railroad bridge specifications. These specifications are now recognized as standard, and are generally used not only as the basis for the design of new metal bridges, but also as a basis for determining the strength of bridges constructed under other specifications. Contracts for bridges are now generally based on unit prices for the actual amount of material used in the construction. Successful competition, therefore, on the part of bridge builders, depends more upon efficiency in methods of construction than upon the actual quantities of materials which are used.

Attention has been called to the fact that, until recently, the rapidity and extent of rolling load increases were neither fully appreciated nor anticipated in the construction of bridges. It is very fortunate for many existing bridges that the stresses produced by these modern, heavy locomotives are not directly proportional to their weights, when compared with the standard typical loading now generally used as a basis for proportioning members. For instance, a 24-wheel articulated engine weighing 616,000 lb. (279,600 kg.) is 2.74 times as heavy as Cooper's E-50, weighing 225,000 lb. (102,150 kg.), but the strains produced are only from 15% to 33% greater. A 16-wheel articulated engine weighing 493,000 lb. (223,820 kg.) is 2.19 times as heavy as the E-50 class, but the strains produced are from 26% to 34% greater. A 20-wheel articulated engine weighing 478,000 lb. (217,000 kg.), 2.12 times as much, produces strains from 1% to 14% greater. The above increases in strains refer to spans under 100 ft. (30.5 m.). They will generally be less for longer spans.

[5] General Specifications for Bridges, B. & O. R. R., 1901.

[6] See Manual of Recommended Practice American Railway Engineering Association, 1911.

Many bridges were built in 1890 to carry a loading equivalent to Cooper's E-30, and in 1900, or 10 years later, a majority of bridges were built for a loading equivalent to Cooper's E-35 or E-40. At the present time they are being built for E-50 and E-60, and locomotives, such as the Atlantic, Prairie, Consolidation, 12-Wheel Pacific, Mikado and the Decapods, now in general service on easy grade roads, are equivalent to Cooper's E-55 to E-60, and Decapod and Articulated types in use on heavy grades are equivalent to Cooper's E-65 to E-70.

The prevailing practice among the majority of railroad companies is to design their bridges for Cooper's E-60 standard loading with the American Railway Engineering Association's standard specifications as a basis. Structures designed in accordance with these standards will carry an overload of 50% in regular service at unrestricted speed, and a much greater overload occasionally, or even regularly, at restricted speed, without impairing their safety. This 50% overload means that these bridges are sufficiently strong to carry Cooper's E-90 loading, and the modern actual service types of locomotives equivalent in their effects are given in the following table.[7]

Full Regular Service Traffic Capacity for E-60 Bridges Based on an Overload of 50%.

Locomotives	Weight	Wheel Base	Aver. Axle Load	Pctge. of Increase[9]
Cooper's E-90	405,000	23.00	90,000	50.0
[8] Atlantic	336,000	31.79	98,800	57.0
Prairie	427,600	34.25	99,100	75.0
Consolidation	411,000	26.50	90,700	58.0
12-Wheel	413,500	27.08	87,600	58.0
Decapod	449,400	29.83	79,500	68.0
Pacific	450,000	35.20	98,000	67.0
Mikado	473,000	35.00	93,500	55.0
12-Wheel Articulated	523,800	30.66	87,100	56.0
10 Coupled	515,800	43.50	86,000	43.0
20-Wheel Articulated	754,800	59.80	85,000	58.0
16-Wheel Articulated	662,500	40.17	75,400	34.0
24-Wheel Articulated	834,000	65.92	74,400	35.0
12-Wheel Electric	552,000	38.50	94,600	84.0
16-Wheel Electric	619,200	44.22	77,400	94.0

[7] "Rolling Loads on Bridges", by J. E. Greiner, Bulletin No. 139, American Railway Engineering Association.

These are the increases in rolling loads anticipated by those railroad companies which build what are known as E-60 bridges; and an examination of the weights of locomotives in the table, with wheel bases as they exist today, will undoubtedly suggest a strong feeling of the physically impossible, unless all present standards of road bed, gauge of track, side and overhead clearances are abandoned and the railroads are practically reconstructed. Those railroads, therefore, which are making provision for the physically impossible in the way of rolling loads are surely building strong enough to take care of whatever is possible in this respect, and they should have no fear that their bridges will not carry all the loads which can ever pass over them. When we consider that even if such excessively heavy types of locomotives are constructed and placed in operation, without changing standard gauge or clearances and without reconstructing our railways, their operation would most assuredly be confined to high grade divisions, and they would not be regularly operated on low grade divisions. If such is the case, then those conservative roads which are designing their bridges for Cooper's E-50 class of loading, which bridges are capable of carrying E-75 without any restrictions whatever (and even E-90 under restricted speed), are anticipating all possible future increases in rolling loads, and at a saving of from 12% to 15% of the cost of E-60 bridges. As there are practically no roads which at the present time build lighter bridges than E-50, it appears that all American railways, at the present time, are profiting by past experience with short-lived railroad bridges and are fully anticipating all possible increases in rolling loads which can be operated over their tracks until their entire lines are reconstructed; and if the next quarter of a century will again record the full life of an American railway bridge it will not be because the increase in the weight of rolling stock has not been anticipated, as has been the case in the past.

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[8] The Atlantic type applies to spans under 15 ft.; for greater spans the weight of this class of engine would run over 90 per cent in excess of the heaviest type now in service.

[9] Percentages of increase in column 5 represent the approximate increase in weight of locomotives and driving axle loads in excess of the maximum weights now in actual service.

In regard to present tendencies, it may be stated that the introduction of new grades of structural steel and the improvements in machinery and in methods of construction are still influences to be considered in future developments. There is a tendency toward the use of alloys with high ultimate strength in the long span bridges, and when these new materials inspire general confidence in their uniformity and reliability for lighter work and their production commercially becomes less expensive, they may gradually replace the present standard structural steel, just as the latter has superseded wrought iron. This, in turn, may require some different types of metal bridges to be designed, so as to take advantage of the greater strength of the metal without sacrificing stiffness in the structure as a whole; or perhaps the present quality of stiffness in metal structures will give place to more elasticity. Another tendency is toward the use of reinforced concrete construction in preference to steel work wherever the conditions are suitable for this type of bridge, and toward continuous ballasted roadbeds over all bridges. There is also a tendency toward the construction of movable bridges revolving in vertical planes instead of in horizontal planes.

These tendencies indicate that the evolution of the American railroad bridges has not as yet reached its final stage, but is still in progress under influences which will continue to direct its trend toward meeting changes in physical and economic conditions.

In conclusion, it may be stated that the recent improvements in American railway bridge practice embrace the substitution of solid-ballasted decks for open decks on short-span, beam-girder bridges and for trestles; of plate girders for short-span, riveted trusses; of riveted trusses for short-span, pin-connected trusses; of stiff bracing and counters for adjustable members; and of concrete and reinforced concrete masonry for cut stone work. While a few years ago the dominating characteristics of American railroad bridge construction were lightness, flimsiness and cheapness, the characteristics of the present day standards are stability, solidity and permanence. These characteristics are illustrated on the plates appended hereto.

APPENDIX.

In order to illustrate the present types of good bridge construction and the improvements which have been made during the past quarter of a century, the following sketches and photographs are appended hereto.

Plate I. This illustrates the open-deck, framed trestle construction and I-beam spans such as were in general use during 1890; and ballasted-deck, timber trestles, reinforced concrete trestles, ballasted-deck I-beam spans, and ballasted-deck plate girders, which are considered the best types at the present time. The sketch of the ballasted-deck timber trestle has been reproduced from the standard of the Seaboard Air Line Railroad; the reinforced concrete trestle is standard on the Chicago, Burlington and Quincy Railroad; and the ballasted-deck plate girders and I-beams are standard on the B. & O. Railroad.

Plate II. This illustrates 153-ft. (46.7 m.) through, pin-connected truss spans, resting on stone masonry, built over the Juniata River at Lewiston, Pa., for the Pennsylvania Railroad, and is typical of the pin-connected bridges which were standard in 1890. Observe the light rods and bracing, and compare with Plate III.

Plate III. This illustrates 152-ft. (46.4 m.) double-track, through, riveted-truss spans, resting on concrete masonry piers, built over the Scioto River at Glenjean, Ohio, in 1910. This is typical of the present standard stiff riveted-truss bridges, and should be compared with the pin-connected truss of about the same span length shown on Plate II.

Plate IV. This illustrates 400-ft. (129.1 m.) single-track, through, connected spans built over the Missouri River at Sioux City in 1888. The adjustable type of lateral bracing is clearly shown on the photograph.

Plate V. This illustrates a part of the Kentucky & Indiana Terminal Railroad Company's bridge, resting on concrete piers, across the Ohio River at Louisville, Ky.; the spans with the curved top chords being 620 ft. (189.1 m.) long. This bridge was built in 1912.

Plate VI. This illustrates a double-track viaduct near Ludlow, Ky., built in 1906. This is typical of the present standard viaducts with steel towers. Note the stiff bracing in the towers. In 1890 this bracing was generally of light adjustable rods. In favorable locations, plate-girder viaducts are frequently constructed with concrete piers in place of the steel towers, in which case the spans are somewhat longer and are of uniform length.

Plate VII. This illustrates a type of movable bridge revolving horizontally on a center pier, which was the standard type of movable bridge in 1890. It was built by the Baltimore & Ohio Railroad across the Calumet River, about 1899.

Plate VIII. This illustrates a double-track through swing-bridge over the Columbia River, at Vancouver, Wash., built in 1907.

Plate IX. This illustrates a double-track Scherzer rolling-lift bascule built over the Cuyuhoga River by the Baltimore & Ohio Railroad in 1911.

Plate X. This illustrates a Strauss trunnion bascule bridge over the Calumet River, Chicago, built by the Chicago and Western Indiana Railroad in 1910.

Plate XI. This illustrates the Willamette River Bridge at Portland, Oregon, which is typical of the American vertical lift bridges.

Plate XII. This is a good stone arch bridge built by the Baltimore & Ohio Railroad over the Brandywine River at Wilmington, Del., in 1910. This is typical of the stone arch bridge which was a standard in 1890. It is a handsome and substantial structure, and there are very few like it being built at the present time, as concrete is considerably cheaper and more expeditiously constructed.

Plate XIII. This is a concrete arch bridge over the Delaware River, at Yardley, Pa., built by the Philadelphia & Reading Railroad in 1914. The concrete in this arch bridge is reinforced with rods merely for the purpose of preventing temperature cracks. It is typical of the present first-class concrete arch construction, and it should be compared with the cut-stone arch construction which was typical of the 1890 standard shown on Plate XII.

Plate XIV. This illustrates a reinforced-concrete slab bridge crossing a boulevard, constructed in 1914 by the Chicago, Milwaukee, and St. Paul Railroad. This is typical of 1915 reinforced-concrete construction.

Plate XV. This illustrates a riveted-truss span with concrete abutments and piers and a plate-girder viaduct, where concrete piers are used instead of metal towers. It was built in 1914 by the Chicago, Milwaukee & St. Paul Railroad and is typical of 1915 construction.

Plate XVI. This illustrates the erection of a truss bridge by means of a gantry traveler; a method of erection which was standard in 1890.

Plate XVII. This illustrates the erection of a truss bridge by means of two derrick cars, and may be considered typical of 1915 methods of truss erection.

Plate XVIII. This illustrates the erection of a plate girder by means of derrick cars, and is typical of 1915 erection methods.

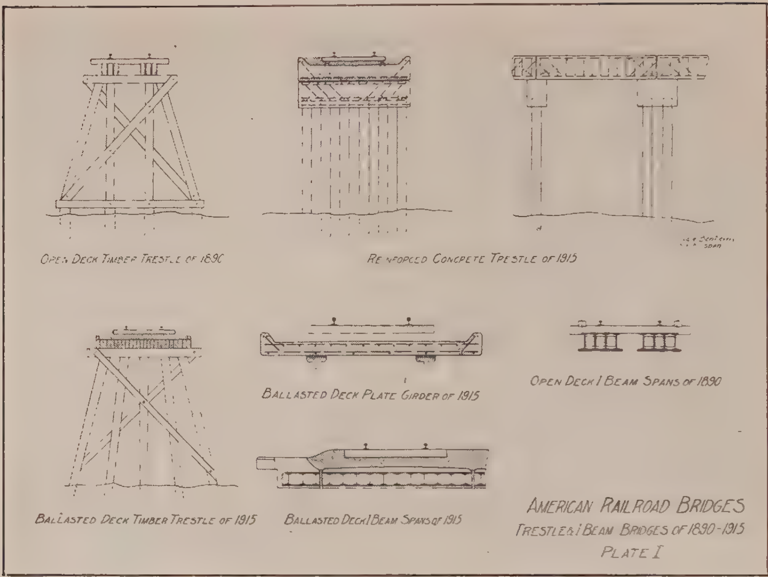

Plate I.

Plate II. 153-Ft. Span Pin-Connected Trusses. Typical of 1890 Construction.

Plate III. 152-Ft. Span Riveted Trusses. Typical of 1915 Construction.

Plate IV. 400-Ft. Span Pin-Connected Truss. Typical of 1890 Construction.

Plate V. 620-Ft. Span Pin-Connected Trusses. Typical of 1915 Construction.

Plate VI. Viaduct with Steel Towers. Typical of 1915 Construction.

Plate VII. Swing Bridge. Typical of 1890 Construction.

Plate VIII. Swing Bridge. Typical of 1915 Construction.

Plate IX. Rolling Lift Bascule Bridge. Typical of 1915 Construction.

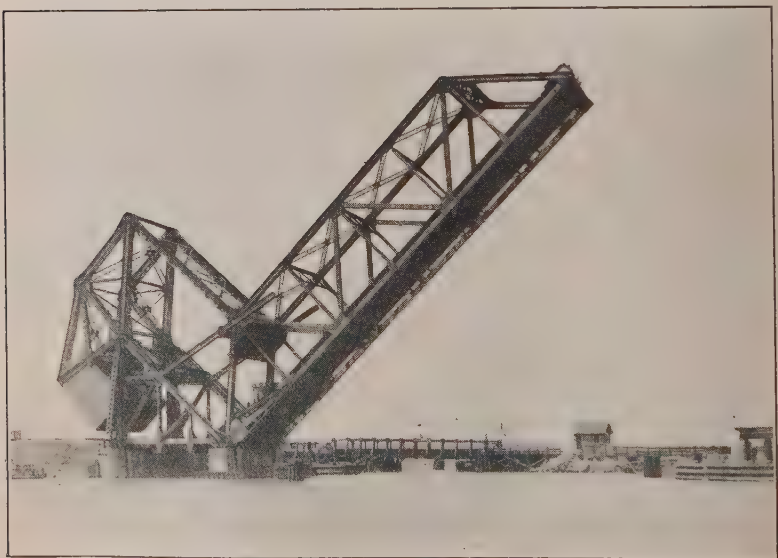

Plate X. Trunnion Bascule Bridge. Typical of 1915 Construction.

Plate XI. Vertical Lift Bridge. Typical of 1915 Construction.

Plate XII. Stone Arch Bridge. Typical of 1890 Construction.

Plate XIII. Concrete Arch Bridge. Typical of 1915 Construction.

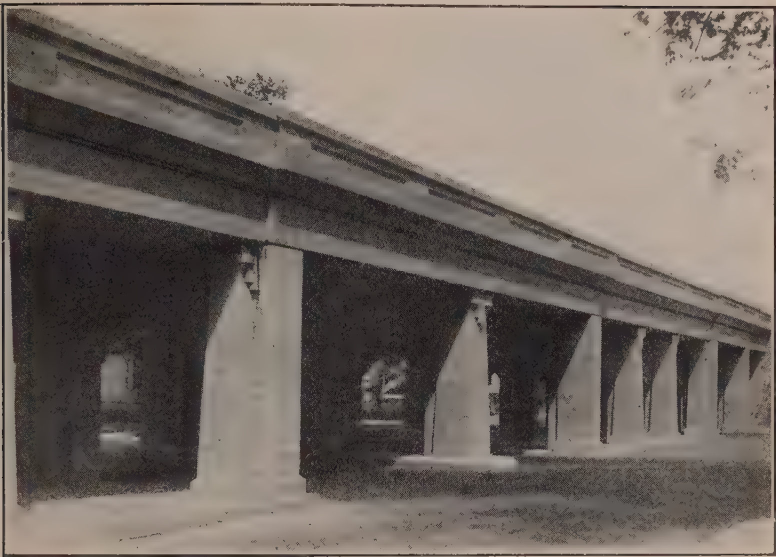

Plate XIV. Reinforced Concrete Slab Bridge. Typical of 1915 Construction.

Plate XV. Concrete Masonry and Viaduct. Typical of 1915 Construction.

Plate XVI. Gantry Traveler. Typical of 1890.

Plate XVII. Derrick Car. Typical of 1915.

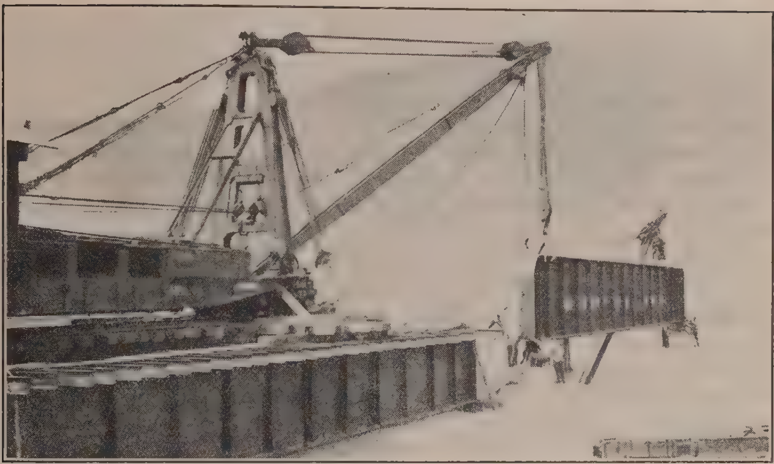

Plate XVIII. Derrick Car. Typical of 1915.

DISCUSSION

Prof. C. Derleth, Jr.,* M. Am. Soc. C. E., expressed the opinion that more and more, where cost will permit, masonry bridges will be used where short spans are possible. There may be the alternation to girder bridges encased in concrete—a reinforced-concrete structure in which the reinforcement is of structural shapes instead of bars or rods. As the paper points out, with spans exceeding 150 ft., the truss type of bridge becomes the desirable one; but the tendency will be to make the floor system as solid as possible, and of a ballasted type with reinforced-concrete covering, where economy and other features make that possible and desirable. Prof. Derleth.

The paper has pointed out repeatedly that the tendency now is to stiff members, eliminating altogether rods and bars as tension members; but in long spans, where mass gives inertia, it would seem that there are certain places where the joints should be left free, as in pin types. There should be certain important places where the joints are movable, notably at the top and bottom of the end post, in order that there may be a readjustment to take out as far as possible secondary strains and kinks.

Prof. Derleth believes it a wrong tendency to propose completely continuous spans for long-span work unless the piers are on rock, so that there will be no unequal settlement. As the spans grow longer, it would seem clear that carbon steel will in a short time be replaced by the alloy steels, just as steel took the place of wrought iron.

Finally, in regard to computations, more and more they should be left to experts who practically do that and nothing else—always in consulta-

* Dean, College of Civil Engineering, University of California, Berkeley, Calif.

Prof. Derleth. tion, of course, with the so-called consulting engineers, who are the first conceivers of the proposition. Computations should eliminate the unnecessary detail of the past, and we should try to state our moving loads in the simplest of forms, leaving the factor of safety to take care of irregularities, particularly as we are uncertain as to what will be the maximum loads during the life of the structure, and because the secondary stresses are an important feature. We should also design the longer spans to get rigidity, but not at the expense of elasticity. The life of a structure will depend upon the avoidance of vibration; so that while we should attempt to make joints solid in the shorter spans, there should be some places where there would be give, to avoid the undesirable features of a continuous span.

Prof. Wing. **Prof. Chas. B. Wing,**† M. Am. Soc. C. E., felt that the papers of the Congress, being statements and compilations of present facts, bringing the subjects down to date, do not readily lend themselves to discussion. It appeared to him that Mr. Greiner's paper clearly brought out the changes in railroad bridges during the past 25 years, and the reasons therefor.

The great bulk of the bridge work of the country is in short-span bridges. The long-span bridges will take care of themselves, as they have to be made the subject of special design. The economy that we get in bridge maintenance must come in a careful study of the shorter span bridges, and therefore the tendencies that are pointed out in this paper are exceedingly interesting.

Prof. Wing believes that in the western part of this country there is still great merit in the wooden ballast deck type of trestle bridge, sometimes of creosoted timber. If protected from water, it needs no creosote. Many such are used on the Southern Pacific Company's lines; and they will probably outlast the steel ones if they are protected from water. The only thing to be renewed is the asphalt coating, and sometimes some guard rails; but these bridges ought to last a great many years, and at a much less cost than steel bridges.

A great expense with steel bridges is in keeping them painted properly. There must be some inaccessible parts, no matter how designed, and we do not know what is going to take place in those inaccessible parts. We have had to renew our steel structures because the increasing engine loads had made them obsolete. Now we are coming, we hope, to the point of building steel structures to take care of all loads, and which will last their full life.

Great attention should be paid to the small details of short-span bridges, especially of steel structures, to see that they are so designed and so erected that the main parts can live their lives, and the bridge not be discarded because some little detail has given out.

Mr. Hood. **Mr. William Hood,*** M. Am. Soc. C. E., wished to correct a misunderstanding regarding ballasted deck trestles. The paper indicates on Plate I,

† Professor of Structural Engrg., Stanford University, Calif.

* Chief Engineer, Southern Pacific Co., San Francisco, Calif.

as well as on page 396, that ballasted deck trestles are of solid timber flooring and constructed of creosoted timber. This was true at one time, but, so far as he was aware, that type has not been built for many years—with the Southern Pacific Company, not for 20 years, more or less. The type was replaced with the use of creosoted timber stringers, spaced suitably and floored over with creosoted plank, on which the ballasted track was laid. This continued until, perhaps, 1898, at which time Mr. Bernard Bienenfeld, M. Am. Soc. C. E., suggested to Mr. Hood that the use of untreated timber obviously would be cheaper for the stringers and flooring; would be very much stronger, and could be protected from moisture by an asphalt roof; and would be thoroughly protected from the sun, which in a good deal of this western country destroys timber almost as much as decay. Since this suggestion, which was promptly adopted, all the ballasted deck trestles on the Southern Pacific lines, including those on the Lucin cut-off, have been built, accordingly, of untreated stringers, suitably spaced, floored over with untreated plank, and then covered with asphalt roofing, with, however, creosoted guard rails, which merely restrain the ballast, and with creosoted caps. Mr. Hood.

Mr. C. F. Loweth,* M. Am. Soc. C. E., said that on the road with which he is connected, the practice is to use a solid line of stringers. His recollection is that they came to that because their trestle spans were 15 ft. 9 in. centers, and in replacing an old-fashioned trestle by a new kind, it was desired to have the new correspond in length with the old; and as it seemed to be about as cheap, it was thought the advantage in having the equal span length was enough to overcome the additional cost that was in the stringers. Mr. Loweth.

He noted Mr. Hood's statement that the stringers are not treated on the Southern Pacific Company's trestles. On the Chicago, Milwaukee & St. Paul it had been the desire to treat them, but they felt justified in using cedar piles. They have had 25 years' life out of white cedar piles, but they are now using Idaho red cedar, and although they do not know how long they will last, they think that they will get as long a life as will justify the expense.

Mr. Loweth thought there is a tendency sometimes to blame the early designers of iron bridges, because they did not look far enough ahead and made their bridges too light. While that may be true, he thought it a question whether they did not build as wisely as we do today. There is a great deal of evolution going on in railroad bridges. Bridges are being taken down, not because they are too light but because we want to change them to double track, because the stream has changed, or because the grade has changed; and, if the bridges had been made very much heavier and had to be removed at this time for those reasons, there would be a larger loss connected with them.

Mr. Loweth has to do with about 130 miles of bridges, and, of course, every year the question of renewal comes up. The problem is not

* Chief Engineer, Chicago, Milwaukee & St. Paul Railway, Chicago, Ill.

Mr. Loweth. so much one of engineering as of finances. There is a limited amount of money. What shall be done with it? Shall some bridges and trestles be replaced with first-class construction in kind? There are very few engineers who are able to say: "We will build everything that we have to build, only along the most permanent lines and in the strongest fashion." Of course, it goes without saying that every bridge has to be strong enough to carry its load. But such bridges can still be built strong enough if they are built of treated or untreated timber, as well as if they were built of concrete or steel. That is not true of bridges of the longer spans, but, as Professor Wing stated, by far the majority of American bridges are of short spans; the longer ones are few and far between.

He wished to take exception to the statement in the paper that the open-deck trestle is justifiable only on light traffic and branch lines.

Mr. Wagner. **Mr. Samuel T. Wagner,**‡ M. Am. Soc. C. E., wrote that the changes in the conditions during the past 25 years in the history of American bridge building have come about gradually but none the less surely, and the manner in which the author presents them makes them appear startling.

Probably the most remarkable change is that of the increased weight of the locomotive as affecting not only the sections of the bridge but also the arrangement of its details to say nothing of the absolute change of type for spans of various length.

Some years ago we thought that the limit of the total weight of locomotives had been reached, at least approximately, because there appeared to be no more available cross-section between the outside lines of the locomotive and the safe clearance lines. Then the idea of the Mallet engine was introduced, and now it seems to be almost possible to believe that the weights might be increased by what years ago seemed almost impossible, viz, the increased cross-section of the locomotive and its encircling clearance line.

In 1904 there was a most interesting discussion of the subject of the increase of engine loading for bridges before the American Society of Civil Engineers (Trans. Vol. LIV, page 78) and it seemed then as if a Cooper E-70 engine was about as far ahead as the mechanical engineers could see, and the author of the paper stated that for general purposes on large railroads it would be unwise to use any heavier loading than a Cooper E-50 engine. Now we are informed that a large bridge has been designed using an E-90 loading. When will it end?

The changes in the details of metal bridges have been most marked and probably in them has been the greatest improvement as affecting the life of the structure. Short-span pin-connected bridges have been almost entirely replaced by riveted connected trusses or plate girders. No detail has received more attention than the floor, that portion of the structure which receives the direct impact from the train. Before 1890 the floor of railroad bridges had been sadly neglected from the point

‡ Chief Engineer, P. & R. Ry., Philadelphia, Penna.

Mr. Wagner.

of maintenance and no part of the bridge suffers more from increase in train loading. Even with all the improvements which have been made, the design of the floor is now receiving much thought in the direction of obtaining greater rigidity and reducing the cost of maintenance. In short-span bridges the use of solid floors of steel or reinforced concrete is increasing. It is a distinct advantage, from an operating standpoint, to have standard ties and ballast in place of special timbers on a bridge, and while from a purely financial point of view it is difficult to show any warrant for the increased cost, yet there are many places where such construction is advisable. The use of a solid floor is of distinct advantage, as far as permanency and rigidity of the structure are concerned.

The changes in the uses of the materials of construction have been most marked. It was possible to obtain wrought iron for structures in 1890, but in the 1893 edition of the Carnegie Steel Company's Pocket Book the note "Our product will hereafter be exclusively steel" occurred for the first time. Carbon steel is the best material for structures of ordinary size, although its rate of corrosion, specially under unfavorable conditions, is so much more rapid than wrought iron as to sometimes make one wish he could get wrought iron as a commercial product. Specifications have been drawn for nickel steel and structures built in which large percentages of this material have been used. On account of its cost it has no value for spans of ordinary length.

Probably nothing has contributed so much to the uniform and satisfactory quality of carbon steel as the practically unanimous adoption of a single grade of steel having an ultimate tensile strength of 60,000 pounds per square inch. This grade is used in practically all ordinary structures.

The increasing use of reinforced concrete in recent years has been remarkable, but probably it has been less used for railroad bridges than for other purposes. In railroad work its use has generally been for short-span slabs or in floors. The writer feels from experience that under the conditions usually existing in a railroad bridge all designs of reinforced concrete should be thoroughly protected by water-proofing in order to prevent the corrosion or electrolysis of the steel.

Probably no single material in railroad work has increased in use more than concrete. Its use for mass work, such as for abutments, piers and arches has been proceeding in leaps and bounds. It is as good as most building stones as far as strength is concerned and is generally cheaper than stone masonry. Its monolithic character makes it much to be preferred for most structures, except where real architectural beauty is concerned, in which case nothing can excel properly prepared natural stone. It is true that in recent years the methods which have been adopted to present a pleasing surface and the architectural care which has been given to the design have resulted in concrete work that is beyond criticism for engineering structures.

Paper No. 87

TRACK AND ROADBED

By

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It is with some temerity that one presents a paper on a subject which is being so thoroughly studied and concerning which such a mass of published data exists, and it is only done with the idea that the individual views of engineers, presented in discussion, may bring forth some new points and may lead to a better understanding of existing data.

The writer's experience for the last seventeen years has been with the rapid transit railroads of New York City. The uniform character of the traffic and its great volume have made it possible to study some parts of the problem, however, especially rail wear, under favorable conditions. His previous experience on several steam railways, and particularly as Chief Engineer of the Union Pacific System (1893-98), might justify a criticism of steam railroad conditions.

The American Railway Engineering Association is making a systematic study of this subject, and in its standardization of the forms of reports is laying a foundation for a more scientific treatment than it has yet received. A special committee of that Association and a committee of the American Society of Civil Engineers is conducting a series of tests to determine stresses in tracks, from which much is expected.

The essential features of the track of the modern railroad, consisting of metal rails supported on wooden cross ties as a runway for wheels having internal flanges, existed in the coal roads of England prior to the application of steam to railroad

TABLE 1. TRACK DATA OF STEAM RAILROADS-1915.

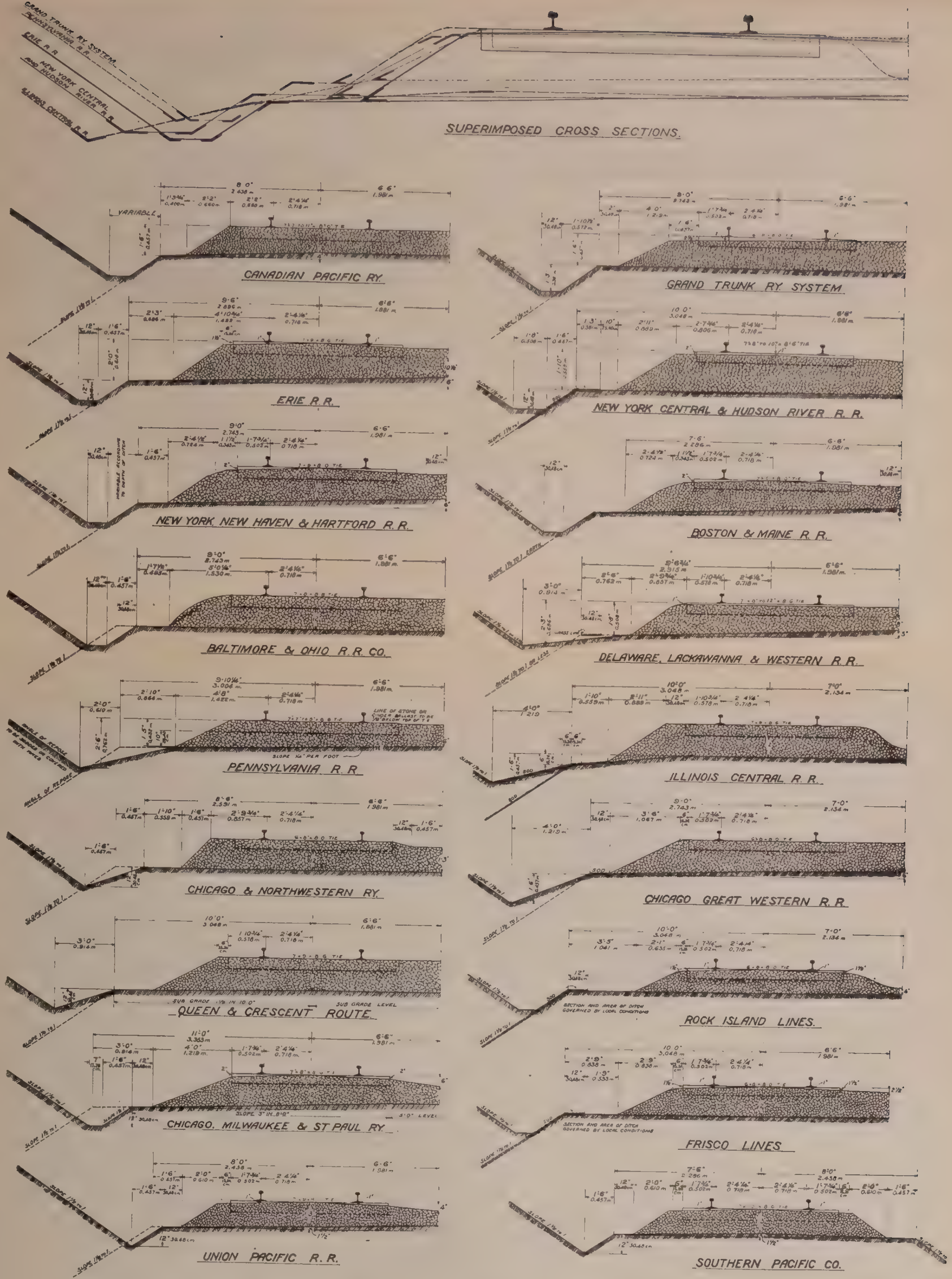
GEO. H. PEGRAM

Name of Railroad	Heaviest Engine Passenger. Weight	Heaviest Engine Passenger. Wheel Base	Heaviest Engine Freight. Weight	Heaviest Engine Freight. Wheel Base	Heaviest Wheel Load	Rail. Weight Lbs. per Yd. Kg. per M.	Rail. Section	Rail. Height	Rail. Open Hearth or Bessemer	Rail. Carbon Content	Length of Splice Bar	Bolts. Number	Bolts. Diameter	Are Tie Plates Used.	Square or Screw Spikes	Cross Ties. Kind	Cross Ties. How Treated	Cross Ties. Size	Cross Ties. Number per Rail	Ballast. Kind	Ballast. Depth under Tie
Baltimore & Ohio	[illegible]# 13330Kg	33'-8" 10.566m	284600# 129160Kg	35'0" [illegible]	[illegible] [illegible]	100# 49.6Kg	ARA-B	[illegible]	O.H.	.62-.75	[illegible] .711m	[illegible]	1" 2.54cm	[illegible]	Square & Screw	[illegible]	[illegible]	[illegible]	18	Stone	12" .305m
Boston & Maine	235000# 106690Kg	33'-3½" 10.147m	[illegible]000# [illegible]Kg	26'0" 7.925m		100# 49.6Kg		5½" 13.97cm	O.H.	.63-.76	24" .610m	4	1" 2.54cm	To a limited extent	Square.	Hardwood, Cedar.	Untreated.	7"x9"x8'0" .178x.229x2.438m	18 to 20	Gravel.	12" .305m
Canadian Pacific			258000# 117130Kg	[illegible] 10.795m		85# 42.2Kg		5⅛" 13.01cm	O.H. Bess.	.55-.70 .50-.60	26" .660m	4	13/16" 2.07cm	Shoulder Tie Plates.	Square.	Various.	Certain amount Creosoted.	[illegible]	16 to 18	Gravel. Broken Stone. Washed Gravel. Crushed Rock	[illegible] .305m
Chicago Great Western	283000# 128480Kg	35'2" 10.719m	353100# 160310Kg	[illegible] [illegible]	27250# [illegible]Kg	85# 42.2Kg	A.S.C.E.	5 3/16" 13.18cm	O.H.	.63-.76	24" .610m	4	⅞" 2.22cm	Yes.	Square.	Oak.		[illegible]	18	Gravel. Stone	[illegible] .305m
Chicago, Milwaukee & St. Paul.			275000# 124850Kg		27850# 12640Kg	100# 49.6Kg	ARA-A.	6" 15.24cm	O.H.		24" .610m	4	1" 2.54cm	On all Softwood Ties and on all Ties on Curves.	Square.	Hardwood. Softwood	$ZnCl_2$ or Creosote or Both. Untreated.	7"x8"x8'-6" .178x.203x2.591m		Gravel.	12" .305m
Chicago North Western					28750# 13050Kg	100# 49.6Kg	C.&N.W.	5 [illegible]" 14.68cm	O.H.	.62-.75	26" .660m	4	1" 2.54cm	Shoulder Tie Plates.	Square.	Hardwood Softwood	Burnett, Wellhouse, Card and Straight Creosote Except for White Oak	7"x9"x8'-0" .178x.229x2.438m	18 to 21	Gravel. Crushed Stone	12" .305m
Delaware, Lackawanna & Western	288000# 130750Kg	34'10" [illegible]	312500# 141880Kg	35'2" 10.719m	[illegible]# 14110Kg	105# 52.1Kg		6" 15.24cm	O.H.	Varies.	28" .711m	6	1" 2.54cm	Shoulder Tie Plates.	Screw.	Oak, Pine.	Lowery Process.	7"x9" to 12"x8'-6" [illegible]	18	Crushed Stone. Washed Gravel.	12" .305m
Erie.	259130# 117650Kg	35'0" 10.668m	853050# 387285Kg	90'0" 27.432m	33600# 15250Kg	100# 49.6Kg	ARA-A.	6" 15.24cm	O.H.	.63-.76	24" .610m	4	[illegible]" 2.50cm	All Softwood Ties. All Hardwood Ties on Curves 1°30' and over.	Square.	Yellow Pine. Oak. Chestnut.	Limited Amount Creosoted	7"x9"x8'-6" [illegible]x2.591m	18	Rock. Gravel	11" .279m
Grand Trunk.			276000# 125300Kg	35'-1" 10.693m	26500# 12030Kg	100# 49.6Kg	ARA-A.	6" 15.24cm	O.H.	.63-.76	24" .610m	4	1" 2.54cm	Only Opposite Joints.	Square.	White Oak, Red Oak.	Untreated. $ZnCl_2$	6"x8"x8'-0" .152x.203x2.438m	19	Gravel.	12" .305m
Illinois Central.			283850# 128870Kg	35'-2" 10.719m	29050# 13180Kg	90# 44.6Kg	ARA-A.	5⅝" 14.29cm	O.H.	.63-.76	24" .610m	4	1" 2.54cm	On Treated and Softwood Ties and on Curves.	Square.	Hardwood Softwood	Red Oak Treated with $ZnCl_2$, Pine Treated Rueping	7"x9"x8'-6" .178x.229x2.591m	20	Stone. Slag. Gravel	12" .305m
New York Central & Hudson River.	272000# 123490Kg	36'-6" 11.125m	284000# 128940Kg	35'-0" 10.668m	30500# 13840Kg	105# 52.1Kg	Dudley	6" 15.24cm	O.H.	.62-.75	36" .914m	6	⅞" 2.22cm	Shoulder Tie Plates.	Square.	Yellow Pine.	Creosoted.	7"x8" to 10"x8'-6" [illegible]	20	Stone.	14 to 22 [illegible]
New York New Haven & Hartford.	200000# 90800Kg	28'2" 8.585m	25[illegible]500# 114180Kg	34'5½" 10.503m	26900# 12210Kg	100# 49.6Kg	ARA-A.	6" 15.24cm	O.H.		24" .610m	4	⅞" 2.22cm	Yes.	Square Screw on Treated Ties	N.C. Pine.	Creosoted.	7"x9"x8'0" .178x.229x2.438m	20	Trap Rock.	12" .305m
Northern Pacific.			320000# 145280Kg	35'3" 10.744m	30000# 13620Kg	100# 49.6Kg	ARA-B	5⅝" 14.29cm	O.H.	.62-.75	24" .610m	4	[illegible]	Yes.	Square	Hardwood Softwood.	Creosoted.	7"x8"x8'0" .178x.203x2.438m	9	Clean Gravel. Cinders Rock	12" .305m
Oregon Short Line.	278000# 126210Kg	35'8" 10.871m	276750# 125640Kg	35'-2" 10.719m	28500# 12930Kg	90# 44.6Kg	ARA-A.	5⅝" 14.29cm	O.H.	.63-.76	27" .686m	4	[illegible] 2.38cm	Yes.	Square	Oregon Fir.	Part Burnettized.	7"x9"x8'0" .178x.229x2.438m	18	Gravel.	8" .203m
Pennsylvania.	293250# 133140Kg	35'2½" 10.731m	330000# 149820Kg	36'-4½" 11.087m	33150# 15050Kg	100# 49.6Kg	P.S.	5 [illegible]" 14.45cm	O.H.	.62-.83	26½" .673m	4	1" 2.54cm	Yes.	Square.	Hardwood Softwood	Certain amount Creosoted.	7"x7" to 9"x8'-6" [illegible]	18	Trap Rock.	10" .254m
Queen & Crescent Route.			269000# 122130Kg	34'-9" 10.592m	28250# 12820Kg	85# 42.2Kg	A.S.C.E.	5 3/16" 13.18cm	O.H. Bess.	.59-.72 .43-.53	24" .610m	4	⅞" 2.22cm	Yes.	Square.	Oak.	Untreated.	7"x9"x8'-6" .178x.229x2.591m	20	Stone. Slag. Gravel.	12" .305m
Rock Island.			318850# 144760Kg	35'-2" 10.719m		100# 49.6Kg	ARA-A.	6" 15.24cm	O.H.	.62-.75	24" .610m	4	1" 2.54cm	Yes.	Square.	Oak. Pine.	Creosoted.	6"x8"x8'-0" .152x.203x2.438m	20	Rock	6" to 12" [illegible]
San Pedro, Los Angeles & Salt Lake	265400# 120490Kg	35'-8" 10.871m			28900# 13120Kg	90# 44.6Kg	ARA-A.	5⅝" 14.29cm	O.H.	.63-.76	27" .686m	4	⅞" 2.22cm	Shoulder Tie Plates.	Square	Oregon Pine Redwood	Burnettized	7"x8"x8'0" .178x.203x2.438m	18	Gravel. Broken Stone	9" .229m
Seaboard Air Line.			285000# 1293[illegible]0Kg	34'-9" 10.592m	26300# 11940Kg	90# 44.6Kg	ARA-A.	5⅝" 14.29cm	O.H.	.62-.75	24" .610m	4	1" 2.54cm	On Turnouts and Curves.	Square.	Pine. Oak.	Untreated.	7"x9"x8'-6" .178x.229x2.591m	20	Gravel. Slag. Stone. Cinders.	
Southern Pacific.	210000# 95340Kg	35'-2" 10.719m	435800# 197853Kg	56'-7" 17.247m	27390# 12430Kg	90# 44.6Kg	ARA-A.	5⅝" 14.29cm	O.H. Bess.	.63-.76 .55-.65	29" .737m	4	⅞" 2.22cm	Yes.	Square.	Oregon Pine.	Burnettized.	7"x10"x8'-0" .178x.254x2.438m	18	Broken Stone, Slag.	8" .203m
Frisco Lines.	240000# 108960Kg	26'0" 7.925m	418000# 189770Kg	56'8" [illegible]	27500# 12480Kg	90# 44.6Kg	A.S.C.E.	5 [illegible]" [illegible]	O.H.	.59-.70	24" .610m	4	[illegible] 2.54cm	Yes	Square	White Oak Red Oak	Untreated Creosoted Lowery Process.	6"x8"x8'0" .152x.203x2.438m	20	Rock Chats Gravel Slag	12" .305m
Union Pacific System.	286117# 129900Kg	35'2" 10.719m	278000# 126210Kg	35'-8" 10.871m	28500# 12930Kg	90# 44.6Kg	ARA-A.	5⅝" 14.29cm	O.H. Bess.	.63-.76 .55-.65	27" .686m	4	⅞" 2.22cm	Yes.	Square.	Oak. Pine. Fir.	Burnettized.	7"x9"x8'-0" .178x.229x2.438m	18	Sherman Gravel. Crushed Rock. Gravel.	8" .203m
Chesapeake & Ohio	341000# 155814Kg		428000# 194312Kg			100# 49.6Kg	ARA-B.	5 [illegible]" 14.29cm	O.H.		24" .610m	4	⅞" 2.22cm	To some Extent	Square	White Oak.	Untreated	7"x8"x8'-6" .178x.203x2.591m	18	Lime Stone. Slag	12" .305m

TABLE 2. TRACK DATA OF ELECTRIC RAILWAYS-1915.

GEO. H. PEGRAM

Name of Railway.	Heaviest Car. Weight	Heaviest Car. Wheel Base Motor Truck	Heaviest Wheel Load	Rail. Weight Lbs. per Yd. Kg. per M.	Rail. Section	Rail. Height	Rail. Length	Rail. Open Hearth or Bessemer	Rail. Carbon Content	Length of Splice Bar	Bolts. Number	Bolts. Diameter	Are Tie Plates Used.	Square or Screw Spikes	Cross Ties. Kind	Cross Ties. How Treated	Cross Ties. Size	Cross Ties. Number per Rail	Ballast. Kind	Ballast. Depth under Tie
Boston Elevated Ry. Co.	125803# 57110Kg	7'-0" 2.134m	18241# 8280Kg	85# 42.2Kg	A.S.C.E.	5⅜" 13.7cm	33' 10.058m	O.H.	.861	24" .610m	4	⅞" 2.22cm	Shoulder Tie Plates	Square & Screw	Hard Pine	Creosote Process in High Pressure Tank and Impregnated with 8 to 10 Lbs. of Dead Oil of Tar per Cu. Ft.	6"x8"x8'-0" .152x.203x2.438m	18	Trap Rock	2" to 5" .051 to .127m
Fonda Johnstown & Gloversville R.R.	100000# 45400Kg	6'10" 2.084m	12500# 5670Kg	80# 39.7Kg	A.S.C.E.	5" 12.70cm	33' 10.058m		.45-.55	32" .813m	6	¾" 1.90cm	On Curves.	Square.	Cedar. Chestnut.	Untreated.	6"x8"x8'0" .152x.203x2.438m	17	Gravel.	6" .152m
Hudson & Manhattan R.R.	87000# 39490Kg	7'-0" 2.134m	10876# 4937Kg	85# 42.2Kg	A.S.C.E.	5⅜" 13.7cm	33' 10.058m	O.H. Bess.	.75-.90 .50-.65	26" .660m	4	⅞" 2.22cm	Yes.	Screw.	White Oak. Yellow Pine.	Untreated. Creosoted.	6"x8"x7'-3" .152x.203x2.210m	22	Broken Stone.	6" to 12" .152 to .305m
Illinois Traction System.	124000# 56290Kg	7'-2" 2.185m	15500# 7030Kg	70# 34.7Kg		4⅝" 11.75cm	33' 10.058m			24" .610m	4	¾" 1.90cm	On Curves only.	Square.	Softwood. White Oak.	Part Creosoted-Lowery Process	6"x8"x8'-0" .152x.203x2.438m	15 & 17	Gravel. Stone. Chats. Cinders.	8" .203m
Interborough Rapid Transit Co. N.Y.	112000# 50840Kg	6'-8" 2.031m	15870# 7200Kg	100# 49.6Kg	RT	5¾" 14.61cm	33' 10.058m	O.H.	.75-.90	24" .610m	4	⅞" 2.22cm	Shoulder Tie Plates.	Square.	Long Leaf Yellow Pine.	Untreated.	6"x8"x8'-0" .152x.203x2.438m	18	Trap Rock.	5" .127m
Lake Shore Electric Ry. Co.	140000# 63560Kg	5'-2" 1.575m	17500# 7940Kg	100# 49.6Kg	ARA-A.	6" 15.24cm	60' 18.288m			34" .864m	6	1" 2.54cm	On Curves.	Square.	White Cedar. White & Yellow Oak	Untreated.	7"x8"x9'-0" .178x.203x2.743m	30	Limestone. Gravel Cinders & Slag.	6" to 10" .152 to .254m
New York State Rys.	50000# 22700Kg	4'-6" 1.372m	6250# 2830Kg	91# 45.2Kg	T-Rail.	7" 17.78cm		O.H.	.70-.90	26" .660m	6	1⅛" 2.86cm	No.	Square.	Softwood. Hardwood.	Untreated when Ties are in Concrete.	6"x8"x8'-0" .152x.203x2.438m		Crushed Stone.	6" .152m
Ohio Electric Ry. Co.	120000# 54480Kg	6'-10" 2.084m	15000# 6810Kg	80# 39.7Kg	A.S.C.E.	5" 12.70cm	33' 10.058m			34" .864m	6	¾" 1.90cm	No.	Square.	White Oak. Chestnut.	Carbolinium.	6"x8"x8'-0" .152x.203x2.438m	17	Crushed Stone. Gravel.	6" .152m
Pacific Electric Ry. Co.				75# 37.2Kg		4 15/16" 12.54cm	33' 10.058m			27" .686m	4	⅞" 2.22cm	All Ties Plated.	Square.	Redwood.	Untreated.	6"x8"x8'-0" .152x.203x2.438m	20	Gravel.	7" .178m
Philadelphia Rapid Transit Co.	75000# 34050Kg	5'4" 1.626m	10500# 4760Kg	90# 44.6Kg	A.S.C.E.	5⅝" 14.29cm	30' 9.144m	O.H.	.68	30" .762m	6	⅞" 2.22cm	No.	Screw.	Yellow Pine	Creosoted.	6"x8"x8'-0" .152x.203x2.438m	16	Trap Rock	5" to 8" .127 to .203m
Public Service Ry. Co. N.J.	58000# 26330Kg	6'-1" 1.855m	7250# 3290Kg	80# 39.7Kg	A.S.C.E.	5" 12.70cm	33' 10.058m	O.H.	.59-.72	24" .610m	4	1" 2.54cm	No.	Square.	Long Leaf Yellow Pine.	10# Creosote.	6"x8"x8'-0" .152x.203x2.438m	17	Broken Stone	6" .152m
Third Avenue Ry. Co. N.Y.	44000# 19976Kg	4'-6" 1.372m	5500# 2497Kg	125# 62.0Kg	Girder.	9" 22.86cm	62' 18.898m	O.H.	.70-.85	32" .813m	8	1" 2.54cm	To some Extent.	Square.	Long Leaf Yellow Pine.	10# Creosote.	6"x8"x7'-0" .152x.203x2.134m	25 & 31	Trap Rock. Concrete.	6" .152m
Union Traction Co. Indiana.	48000# 21790Kg	6'-0" 1.829m	6000# 2724Kg	80# 39.7Kg	A.S.C.E.	5"	33' 10.058m	O.H. Bess.	.46-.59 .35-.45	24" .610m		¾" 1.90cm	Few.		Cedar. Oak. Chestnut.	3 Lbs. Creosote Oil & ½ Lb. $ZnCl_2$ per Cubic Ft. of Tie.	6"x8"x8'-0" .152x.203x2.438m	17	Gravel.	12" .305m
Washington Baltimore & Annapolis Electric R.R.	80000# 36320Kg	6'-6" 1.981m	10000# 4540Kg	80# 39.7Kg	A.S.C.E.	5" 12.70cm	33' 10.058m			32" .813m	6	⅞" 2.22cm	To some Extent.	Square.	Chestnut. White Oak.	Untreated.	7"x9"x8'-0" .178x.229x2.438m	17	Gravel	6" to 12" .152 to .305m
Northern Ohio Traction & Light Co.	80000# 36320Kg	6'-0" 1.829m	10000# 4540Kg	95# 47.1Kg	T-Rail.	7" 17.78cm	60' 18.288m	O.H.	.80-.85	24" .610m	4	1" 2.54cm	No.	Clip.	Carnegie Steel Tie. #M 25.		4⅝"x7'-0" .114x2.134m	20	Concrete.	6" .152m



CROSS SECTIONS OF STONE BALLAST ROADBEDS FOR STEAM RAILROADS - 1915.

TRACK AND ROADBED.

GEO. H. PEGRAM

Plate I.

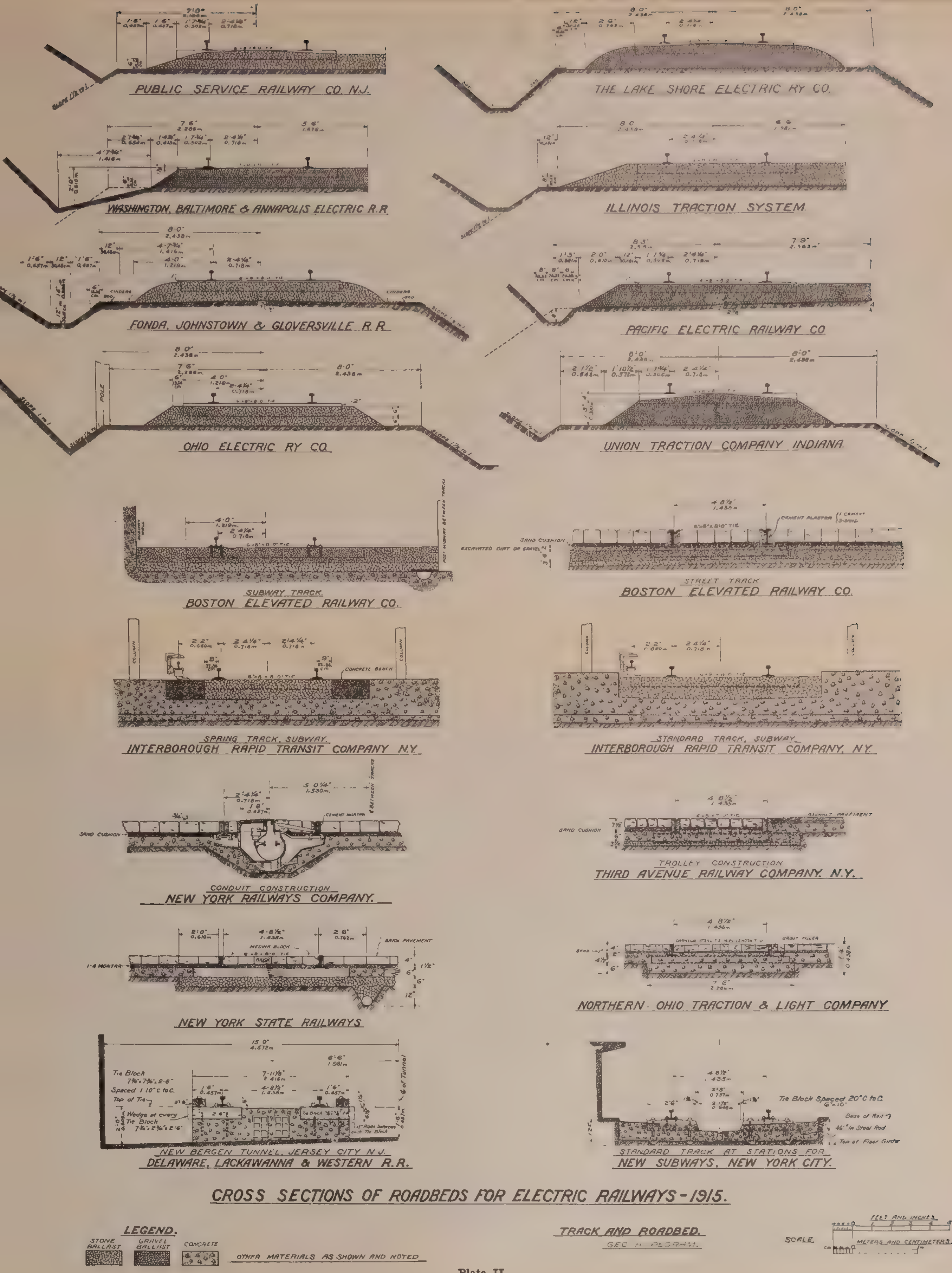

PUBLIC SERVICE RAILWAY CO. N.J.
THE LAKE SHORE ELECTRIC RY. CO.
WASHINGTON, BALTIMORE & ANNAPOLIS ELECTRIC R.R.
ILLINOIS TRACTION SYSTEM.
FONDA, JOHNSTOWN & GLOVERSVILLE R.R.
PACIFIC ELECTRIC RAILWAY CO.
OHIO ELECTRIC RY. CO.
UNION TRACTION COMPANY INDIANA.
SUBWAY TRACK
BOSTON ELEVATED RAILWAY CO.
STREET TRACK
BOSTON ELEVATED RAILWAY CO.
SPRING TRACK, SUBWAY.
INTERBOROUGH RAPID TRANSIT COMPANY N.Y.
STANDARD TRACK, SUBWAY
INTERBOROUGH RAPID TRANSIT COMPANY, N.Y.
CONDUIT CONSTRUCTION
NEW YORK RAILWAYS COMPANY.
TROLLEY CONSTRUCTION
THIRD AVENUE RAILWAY COMPANY. N.Y.
NEW YORK STATE RAILWAYS
NORTHERN OHIO TRACTION & LIGHT COMPANY
NEW BERGEN TUNNEL, JERSEY CITY N.J.
DELAWARE, LACKAWANNA & WESTERN R.R.
STANDARD TRACK AT STATIONS FOR
NEW SUBWAYS, NEW YORK CITY.
CROSS SECTIONS OF ROADBEDS FOR ELECTRIC RAILWAYS-1915.
LEGEND.
STONE BALLAST
GRAVEL BALLAST
CONCRETE
OTHER MATERIALS AS SHOWN AND NOTED
TRACK AND ROADBED.
SCALE.
FEET AND INCHES.
METERS AND CENTIMETERS.

Plate II.

transportation, and strangely, of the same gauge that is in common use in the United States today.

The design is admirably adapted to the conditions of service. The frequent fastenings of the rails preserve the gauge and secure temporary alignment of the parts of a broken rail; the cross ties form a platform upon which derailed wheels may run, and the rails and ties together form an elastic medium to distribute the weight of moving loads over the roadbed.

The details of roadway are of course varied to suit different conditions; as for instance, in a snow country the roadway is made as much as possible in embankment, and cuttings are made wide enough to permit the track to be cleared. There are variations in practice, however, under like conditions, which are largely due to our limitations of knowledge and experience, and which a general discussion of the subject will help to remove.

In this, as in everything else, progress will depend largely upon the individual, and such studies and experiments as Doctor Dudley and others have made are very necessary.

The improvements in the past decade have been in the more extended use of open-hearth high-carbon steel rails and in the rapidly increasing use of treated ties. The introduction of screw spikes has also taken place, but to what an extent it is an improvement, time is required to determine. Their extended use in Europe has been largely in different kinds of timber and under lighter loads.

In order to illustrate the present, best American practice, data have been obtained from engineers of the various roads, from which Plate I, showing cross sections of the roadbeds, and Table 1, giving the details of track and roadbed, have been prepared.

Several of the cross sections show sod; and if grass and other growths are to be maintained, proper conditions must be provided. Probably no greater improvement can be made in our roadbeds than studied and persistent efforts to secure the growth of grasses and vines. This requires gentle slopes, rounded corners, proper drainage, and above all, permanent support for the toe of the slope. Ditches in a cutting are often cleaned out and the toe of the slope removed, regardless of the fact that the whole face of the slope will move to restore the equilibrium.

ELECTRIC RAILWAYS.

While electric railways are mainly street-car lines, they extend into the rural districts, and steam railroads are being electrified near large cities, so that it seems proper to include them in this paper.

The cross sections of the roadbed are shown on Plate II and the details of construction are given in Table 2.

The underground electric-conduit construction is in such limited use that it will not be discussed except to call attention to a defect in most of those which have been built, namely, failure to properly brace the track rail against the pull of the tie rod connecting it with the slot rail, by a lug or brace on the yoke. The track rails are generally fastened to the yokes with bolts, the heads of which project over the flanges of the rail and which become loose and yield to the pull of the tie rod, allowing the slot to be closed through the expansion or swelling of the street pavement.

Electric railway construction, in cities where the streets are paved, requires the use of girder-section rails. While bolted splice plates are generally used, welded joints seem to be now preferred. A joint made by welding the edges of the splice bars to the head and base of the rail promises well. While a welded joint costs about twice that of a bolted joint, the better riding of the track, greater durability of the rails, and in cities like New York, saving in repairs of paving made necessary by loose joints, justify the use of the welded joint.

Special forms of track are sometimes used in tunnels and subways. The Delaware, Lackawanna & Western Railroad has a short tie construction in its Hoboken Tunnel. The ties are imbedded in concrete, which comes to the top of the ties, and are held in place by wooden wedges.

At the new stations of the New York Subway similar short ties are used, but they are fastened to the concrete, which comes to the top of the tie, with bolts set in the concrete.

The Interborough Rapid Transit Company uses the spring track, shown in Plate II, in the East River Tunnels and at points where it is necessary to lessen the vibration, caused by the trains, to adjacent buildings. The small clearances in the tunnels fur-

ther required a fixed location of the track. In this track the ends of the ties, of the usual cross-tie construction, are supported on concrete benches located sufficiently outside of the rails to permit deflection of the ties. The space under and between the ties is filled with broken stone, to permit drainage and to prevent the accumulation of rubbish. This track has been in use nine years with good results.

CROSS TIES AND FASTENINGS.

Cross ties, as the largest item of track expense, merit special consideration, particularly as the conditions attending their use are so rapidly changing.

The hardwood untreated cross tie probably makes the best track that can be devised. Its superiority over the steel and concrete ties consists in elasticity, facility of making fastenings, resistance to displacement in the ballast, insulation of electric currents and especially toughness against destruction by derailed wheels. Its superiority over the treated tie of equally good material is in greater hardness, strength and toughness. It is, therefore, not surprising that untreated ties are often used in places where economy alone would seem to dictate the use of treated ties.

Steel and iron ties cannot be said to be used in the United States, except in an experimental way, but we are interested in their development and will appreciate any discussion of their merits by those who have had experience in their use.

We have reached the time when, generally, we must preserve our ties by treatment. The investigations of the Forestry Service of the United States Department of Agriculture are furnishing valuable data for our guidance, in addition to the work of the engineering societies. Time is still needed to reach definite conclusions regarding many details—for instance, the relative efficiency of different treatments under various climatic conditions; the comparative efficiency of screw spikes in different kinds of timber, as against cut spikes; etc.

The present conclusions point to the following as desirable:

1. The use of sawed cross ties treated with creosote or zinc chloride. The sawed tie gives the most uniform support for the

rails and the best bearing for the tie plates. The amount of sapwood need not be restricted, because the sap is most susceptible to treatment. This will lead to the greatest conservation of the timber supply.

2. The process of treatment should not heat the wood above 110° C. Ties which are overheated are made brittle.

3. Tie-plates should be used on all treated ties, and on soft wood ties whether treated or not.

4. The tie-plate should have a flat bottom, so as not to cut into the tie and allow the entrance of water. It may be desirable to use corrugations or ribs on top of the tie plate to give distribution of pressure lengthwise of the tie. In such cases, screw-spikes should be used on account of the length required.

5. When screw spikes are used, the head of the screw spike should be supported by a boss on the tie-plate sufficiently high to prevent the spike from bearing on top of the rail flange. Time and experience are still wanting to prove the merits of screw spikes as compared with cut spikes.

6. Where cut spikes are used in treated timber, they should be driven in bored holes 7/16 inch by 4 inches. The interior of the holes should be treated before driving the spikes, and preferably when the ties are treated. Timber is rendered short-fibred or brittle by treatment, and unless the spike is driven in a bored hole, it will break up the fibres.

7. It is believed that cut spikes should be driven into hardwood untreated ties without previous boring, because the fibres are deflected rather than broken; and while the material around the spike is injured, the compression induced by the spike will tend to preserve the pressure.

8. The use of the tie-plates facilitates tilting the rail normal to the coning of the wheel of the car, if desired, by making it with a beveled rail seat or by dressing the bearing on the ties to a bevel.

While the tilted rail has not been used in the United States, there are indications that it might be used to advantage, particularly in view of the observations of Mr. James E. Howard, United States Engineer Physicist, that transverse fractures occur on the gauge side of rails. (See Report to Interstate Commerce Commission of accident on the Lehigh Valley Railroad at Man-

chester, N. Y., on Aug. 25, 1911, and report of August 15, 1913, on the Louisville & Nashville wreck near Haymill, Ala., Oct. 1, 1912.)

9. The present tendency is to the use of the four-bolt joint, but it is believed that the six-bolt joint will ultimately prove better. It is essential, in either case, that the bolts shall be made of steel, of good quality, with high elastic limit.

10. Anti-creepers should be used on all tracks having one-way traffic, particularly on grades.

RAILS.

It has been claimed that the railroad track has not been as scientifically studied and analyzed as other engineering problems. It has not been susceptible of very exact analysis because of the great variety of physical conditions and the economic limitations. The attention now being given to this subject by the railroads, engineering societies, the Government and the manufacturers gives promise of better results in the future.

The rail presents the most serious problem. The responsibility for loss of life through wrecks that may be caused by broken rails makes us timid in treating the problem in a broad, economic way. With the increase of wheel loads and speeds, we naturally increase the weights of the rails. When the rail breaks, we cover our doubts as to the quality obtainable by further increase in weight. There are, however, reasons, aside from economy, why the rails should be made of small section. The small rail will distribute the load over a poor roadbed with less proportionate stress, because of its greater flexibility, and it can be made of better quality. This was brought forcibly to the writer's attention on the Union Pacific Railroad in 1894 during the replacement of the old English 56-lb. rails with 75-lb. American rails, where it was necessary to begin the replacement of the 75-lb. rails before the 56-lb. rails had been completely removed.

These 56-lb. rails were carrying passenger engines having a weight of 38,000 lbs. per axle, while the heaviest axle load now running on the present 90-lb. rails is 56,500 lbs., from which it will be seen that the 56-lb. rail was subjected to stresses 50 per-cent greater than the present 90-lb. rail.

The Report of the American Railway Engineering Association (Proceedings of the Year 1914) states: "The average performance of the heavy sections (85 lb. to 100 lb.) is not as good as that of the lighter sections (72 lb. to 80 lb.)".

In Technologic Paper No. 38 of the United States Bureau of Standards (1914) it is stated: "One of the most important factors in the determination of the grain size of the rolled piece is the amount of reduction in the rolls. A comparison of the results given in Table 23 shows that for two rails finished at practically the same temperature, the one having the smaller cross section is very much finer grained. The average grain size of the 90-lb. and 100-lb. rails is 24,000 per square inch, while that of the 72-lb. rails is 42,800 per square inch". And on page 61 of the same paper: "With uniform mill practice the rails of 100-lb. section will be finished at some 10 to 20 degrees hotter than 90-lb. rails and 50 degrees hotter than 75-lb. rails."

It is essential that standard sections shall be generally used. This will not only conduce to economy in manufacture but will permit better comparisons of service to be made. This object would not seem to be accomplished by having standard A, B and C sections of rail of the same weight as one society now proposes, and yet the writer recalls an experience which would justify such practice. For example, the New York subway was originally laid with A.S.C.E. 100-lb. rails and it was desirable to continue the use of such an accepted standard. It was found, however, that the sharp corner of the rail wore off so rapidly and cut into the wheels so badly that it was necessary to increase the radius of the corner from standard of 5/16 inch to 1/2 inch; and thus a new section was born.

To have a section universally used, consideration must be given to what seems to be the extreme requirements of some of the users. It is, of course, necessary to accept the dictation of the mills as to desirable shapes to roll.

The admirable report on rail failure statistics for the year ending October 31, 1912, published in the Proceedings of the American Railway Engineering Association for the year 1914, furnishes the best data we now have. Attention is called in this report to the fact that consideration is not given by the roads replying as to the differences in wheel loads, speed, tonnage over

the rails, and it might be added, the character of the roadbed. These elements are, of course, essential to enable conclusions to be drawn.

On the New York City rapid transit lines, rails of various kinds have been tried and careful records kept of their service. The rails are of 90-lb. and 100-lb. sections. While the wheel loads are only half of those on the steam railroads, the uniform character of the roadbed and the facilities for exactly measuring the tonnage carried permit exact deductions to be drawn. This experience clearly confirms one of the conclusions of the A.R.E.A. Report above referred to, viz., "The wide variations of results must be due, to a large extent, to a lack of uniformity in the performance of different mills, and also to a lack of uniformity in the product of any individual mill".

The averages of all rails used on the New York rapid transit lines show that the open hearth 100-lb. rail with carbon 0.75 to 0.85 and phosphorus 0.02 to 0.04 gives twice the service against wear with only one half the number of breakages, in the same length of time, as the Bessemer rails having carbon 0.50 to 0.60 and phosphorus 0.10. Still there have been Bessemer rails that gave practically the same service as the open-hearth rails. In two lots of open-hearth steel rails, rolled under the same specifications, by the same mill, in the same year, the breakages from one lot were five times the number from the other lot.

A paper by Mr. O. O. Dixon, read October, 1914, before the New York Railroad Club, gives data on the wear of rails in the New York Subway.

It is believed that more attention should be given by the railroads to securing better wearing rails. It seems probable that the carbon content of open-hearth rails can be increased 0.10, or specified 0.72 to 0.85, with advantage, inasmuch as the phosphorus content can be made considerably less than 0.04. While the higher carbon may cause slightly more breakages, we must consider where the line should be drawn, and by improved mill operation, extend it as much as possible. The objections made to this are, that there is a higher percentage of failures in the high-carbon rails and that transverse fractures are more often found in the high-carbon rails. As Mr. Howard has pointed out, these fractures always occur on the gauge side of the rails after

they have been in service, and this is confirmed by other observers. In view of this, it may be wise to lay our rails normal to the coning of the wheel rather than normal to the axle, as at present, and thus get a more central pressure on the head.

In the matter of inspection, it would seem best to make the chemical determination from borings from the finished rails; and instead of taking test specimens for physical tests from three ingots of the heat, as at present, it would be better to test the top of the "A" rail of each ingot, and if this fails, test a specimen from the bottom end of the "A" rail for the acceptance of the "B" rail, etc. This will add to the cost of production, but would seem to be a wise insurance against breakage in the track.

In the United States Technologic Paper No. 38, previously alluded to, reasons are given for finishing the rails at a lower temperature to secure a finer grain structure, which would be practically accomplished by specifying a less shrinkage allowance.

In a paper on the "Effect of Finishing Temperatures of Rails on Their Physical Properties and Micro-structure", by Mr. W. R. Shimer, read at the New York meeting of the American Institute of Mining Engineers, February, 1915, and giving the results of experiments made at the Bethlehem Steel Works on re-heating blooms, it is shown that when rails are rolled from blooms charged hot into a re-heating furnace and brought up to about the original ingot rolling temperature before rolling into rails, "no appreciable difference in grain was found to indicate that the size or structure was governed by the difference in finishing temperatures".

The Lackawanna Steel Co. has introduced a de-seaming process, which consists in milling about 1/8 inch from the top and bottom of the ingot during the rolling into rails.

A small lot of steel rails rolled from ingots poured with the big end up have been tried in the New York Subway, and have had no failures and appeared to be of a more homogeneous structure.

It is thus apparent that the mills are alive to the necessity of producing better rails, and it is certainly in the mills that improvements must be made.

Our rails will probably cost more, but the railroads can well afford to pay for longer wear and greater safety.

Careful experiments are now in progress, by engineering societies, on track deflection. It is apparent that the general deflection of the roadbed under a locomotive causes tension in the base of the rail, which, combined with the local effects of wheel loads, would require the base of the rail to be made proportionately larger than the head.

The recent increase in the base of rail to prevent the flange breaks due to transverse stress would also tend to meet the requirements for this longitudinal stress.

Dr. P. H. Dudley's Stremmatograph records yield valuable information as to the stresses in rails due to track depression, and show the manner in which the stresses are affected by the distribution of wheel loads and speed.

Unless the use of vanadium steel, which has not yet had a service trial, justifies its increased cost of 30 percent, it may be stated that open-hearth high-carbon steel now holds the field against the metal alloyed steels.

Rolled manganese-steel rails, used in places of rapid wear, will give about five times the service of open hearth steel, but in electric railway service it has proved more susceptible to corrugation and breakage. The fractures, however, are of a progressive nature and are generally discovered by inspection before ultimate failure. The present specified composition of manganese-steel rails is:

Carbon	1.00 to 1.40%
Manganese	11 to 15%
Phosphorus	Not over 10%

Conductor, or "third", rails are now obtainable at about the price of running rails, which have a conductivity less than one-seventh that of copper.

The results of tests of 36 heats of open-hearth 100-lb. conductor rails recently rolled were as follows:

	Carbon	Manganese	Sulphur	Phos.	Sil.
Minimum	.060	.05	.028	.007	.005
Maximum	.190	.25	.045	.023	.015
Average	.074	.18	.033	.014	.009

Ratio to copper: Minimum, 6.20. Maximum, 6.68. Average, 6.68.

Such rails are too soft to handle conveniently or to give the proper wear, and experiments show that the carbon content

can be made 0.15 and still keep the ratio of conductivity below 7.

The literature on this subject is so voluminous that aside from the Proceedings of engineering societies, reference is only made to the following publications of special interest:

"Conservation of Cross Ties by Means of Protection from Mechanical Wear", J. W. Kendrick, Am. Ry. Engineering & Maintenance of Way Assn., March, 1915.

"Report of Accident on the Wabash R. R. near West Lebanon, Ind., March 7, 1912", Interstate Commerce Commission, Aug., 1912.

"Experiments on the Strength of Treated Timber", W. Kendrick Hatt, PhD., Circular No. 39, July 20, 1906, U. S. Forest Service.

"Experiments with Railway Cross Ties", H. B. Eastman, Circular No. 146, April 25, 1908, U. S. Forest Service.

"Cross Tie Forms and Rail Fastenings, with Special Reference to Treated Timbers", Herman Von Schrenk, Bulletin No. 50, 1904, U. S. Forest Service.

"Service Tests of Ties", Howard F. Weiss and Carlile P. Winslow, Circular No. 209, December, 1912, U. S. Forest Service.

"Prolonging the Life of Cross Ties", Howard F. Weiss, Bulletin No. 118, Nov. 9, 1912, U. S. Forest Service.

"Experiments in the Preservation Treatment of Red Oak and Hard Maple Cross Ties", Bulletin No. 126, May 26, 1913, U. S. Forest Service.

"On the Finishing Temperatures and Properties of Rails", Dr. G. K. Burgess, et al., Paper No. 38, U. S. Bureau of Standards (1914).

"Report of Accident on the Louisville and Nashville Railroad near Hays Mill, Ala., Oct. 1, 1912", Interstate Commerce Commission, 1913.

"Unit Fibre Strains in Rails from Moving Wheels, Recorded and Elucidated by the Stremmatograph", Dr. P. H. Dudley.

"Typical Rail Failures", F. A. Weymouth, New England R. R. Club, Nov. 10, 1914.

"Distinctive Features of Track Equipment of the New York Subways", O. O. Dixon, New York R. R. Club, Oct. 16, 1914.

"Electric Railway Track Construction", R. M. Hannaford, Canadian Railway Club, Feb., 1913.

"Rail Sections as One Element in Steam and Electric Traction", P. H. Dudley, General Electric Review, Nov., 1914.

"Report of Accident on the Line of the Lehigh Valley R. R. near Manchester, N. Y., Aug. 25, 1911", United States Interstate Commerce Commission, 1912.

"Report of Accident on the Great Northern Railway near Sharon, N. D., Dec. 30, 1911", U. S. Interstate Commerce Commission.

"Effect of Finishing Temperatures of Rails on Their Physical Properties and Micro-structure", W. R. Shimer, Amer. Inst. Mining Engineers, March, 1915.

DISCUSSION

Mr. Charles Whiting Baker,* Mem. Am. Soc. M. E., noted that the author introduces the question of its being worth while to tilt the rail. It appeared to him to be worth pointing out that the rail and the wheel are one machine, and that we cannot consider what the rail should be without considering at the same time what the wheel actually is. He referred to a very remarkable paper which was read some years ago by the Nestor of the profession, Don G. Whittemore, in which it was shown that the actual wheel rolling on the actual rail is a cylinder rolling on a flat surface, and not a cone. If we take a section, we find that, instead of the standard contour of the new wheel, we have quite a variety of shapes, some worn with hollow treads and some that are cylinders; and the rail has to adjust itself to those conditions. A rail after it has been in the track a little while is worn off apparently level on the top. It is worth considering whether the elimination of the refinements mentioned—coning the wheel, etc.—might not result in better wear. In that case there would be no necessity for tilting the rail. Mr. Baker.

Mr. Arnold Stucki,** Mem. Am. Soc. M. E., said that undoubtedly the wood tie is the most economical in certain sections of the country where timber is available and steel is hard to get; but there are localities where these conditions are just reversed. Several roads have had this experience. He thought it unfortunate that Mr. H. T. Porter, Chief Engineer of the Bessemer and Lake Erie Railroad, was not present to speak of his experience with steel ties, for his entire road is equipped with them. Mr. Stucki.

Mr. W. A. Cattell,† M. Am. Soc. C. E., stated that the principal trouble with steel ties is that no satisfactory means have yet been devised of fastening the rail to the tie. The adoption of the steel tie is not so much a matter of the relative cost and durability of the steel and wood, but of the efficiency of the fastening. If a satisfactory fastening could be developed, steel ties would soon come into more general use. Mr. Cattell.

Mr. William Hood,‡ M. Am. Soc. C. E., wrote concerning the top finish of a roadbed in cuts or fills, preparatory to track laying and subsequent ballasting, supposedly on account of future drainage, that Figs. 1 and 2—single track cut on tangent and on curve—show half width of cut as 9 feet, the corresponding half width of bank being 8 feet, which are ordinary and normal suitable construction, to be varied from according to climate and according to the importance of the railroad. Mr. Hood.

Both of these figures show an irregular line in general underneath the finished line marked ''profile or formation grade''; this irregular line being illustrative of the ordinary shape of a cut or fill roadbed as graded by ordinary appliances, ready for finishing to surface ready for track laying.

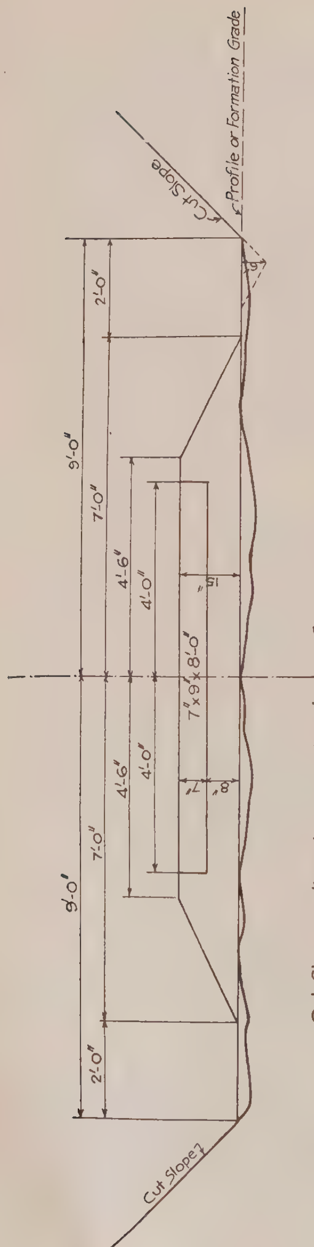
* Editor-in-Chief, Engineering News, New York, N. Y.

** Consulting Engineer, Pittsburgh, Pa.

† Consulting Engineer, San Francisco, Calif.

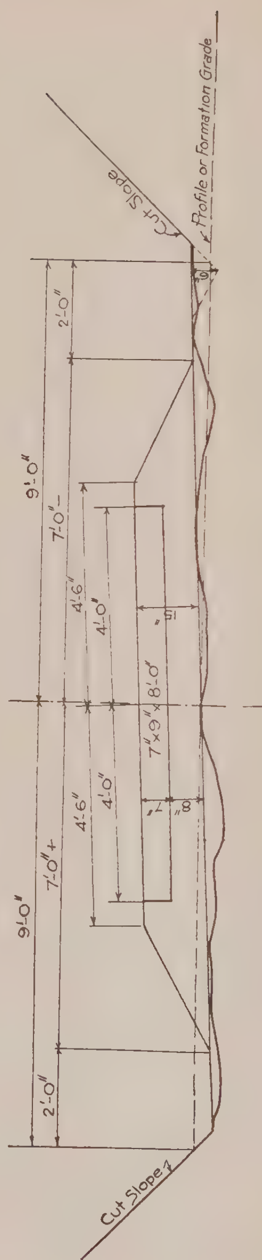
‡ Chief Engineer, Southern Pacific Co., San Francisco, Calif.

Mr. Hood.



Cut Slope ordinarily varies from $\frac{1}{4}$:1 to $1\frac{3}{4}$:1, per material.
Irregular Line illustrates shape of roadbed ready for finishing.

Fig. 1. Single Track Cut on Tangent.



Cut Slope ordinarily varies from $\frac{1}{4}$:1 to $1\frac{3}{4}$:1, per material.
Irregular Line illustrates shape of roadbed ready for finishing.

Fig. 2. Single Track Cut on Curve.

Mr. Hood.

The material then put on and smoothed to formation grade on tangents, and to transverse slope on curves, is the most suitable material readily at hand. If possibly the adjacent cuts contained material as good as ballast, or partially as good as ballast, this material would be used.

In no case is the top of the resulting smooth surface ready for track-laying to be considered waterproof and capable of shedding water, regardless of the shape that it may be put into. Hence, it may be considered that the only practical utility of such smooth surface is for (1) convenience of track laying and first running surface and (2) for ensuring uniform depth of ballast under the ties.

On banks this condition is not permanent, and whatever the shape they are top-finished to, it soon disappears after settlement and is corrected by track raising with more ballast.

The dimensions of ditches should be determined by climatic requirements and are located either on both sides or only on one side of the cut; or in some instances there are no ditches at all.

Excessive half widths of cuts in mountainous regions, steep transverse slope canyons, etc., give a cost of construction which is best appreciated by those who have had experience and profited by it.

In close work of this sort, where benched line to hold the ballast is required on the lower side, the difference between 9 and 11 feet half width can readily double an already heavy cost of grading.

Mr. Eckart.

Mr. N. A. Eckart,* M. Am. Soc. C. E., felt that inasmuch as electric railways have been included in the scope of this paper a brief description of the track and roadbed construction of the San Francisco Municipal Railways may be of interest to the visiting members, most of whom have doubtless had occasion to ride over the Municipal Road to the Exposition.

The standard construction of the Municipal Railways, briefly summarized to correspond with the column headings of Table 2 of the paper, is as follows:

Heaviest Car, weight 50,000 pounds; wheel base, motor truck 4 ft. 10 in.

Heaviest Wheel Load, 6250 pounds.

Rail: 106 pounds per yard in straight track,
129 pounds per yard on curved track,
70 pounds in open track construction.

The 106- and 129-pound rail are grooved girder sections, 9 in. deep; standard lengths are 60 and 62 feet, and 30 and 32 feet respectively; the 70-pound rail is the A. S. C. E. section, 4⅝ in. deep, and 33 feet standard length. All rails are of open hearth steel, purchased under the Standard Specifications of the American Society for Testing Materials; the carbon content of the girder rail being as per Class "A".

* Assistant Engineer in charge of Municipal Railway Construction, San Francisco, Calif.

Mr. Eckart. Splice bars for the girder rail are 36 inches in length with twelve 1-inch bolts, and for the "T" rail are 34 inches in length with six ¾-inch bolts. Shoulder tie plates are used throughout, and square spikes. Crossties are split California redwood, untreated, and are 6 in. by 8 in. by 8 feet long, spaced 2 feet on centers. Ballast is crushed rock 8 inches deep under the ties.

Briefly the method of construction in paved streets is as follows:

The track trench is excavated between lines 2 feet outside of the outer rails. The pavement, when of asphalt on concrete base, is broken by means of a 2500-pound pile-driving hammer, with an 8- to 10-foot drop, the pile-driving rig being so mounted that the hammer may be swung back and forth across the width of the trench as it progresses along the line. Following this the asphalt surface is easily separated from the concrete base, loaded by hand into trucks, and hauled away. The shattered concrete is then thrown to one side and a small steam shovel, generally of one-half yard capacity and of the merry-go-round type, is used for completing the excavation to subgrade, which is 23½ inches below the finished rail surface. The bottom of the trench is then flushed with water and rolled with a 5- to 7-ton roller; in clayey material flushing is omitted, and in sand rolling is omitted. Upon the subgrade thus prepared 6 inches of broken rock ballast is spread, or, where available, the broken concrete paving base, crushed to size, is used. This is then covered with sufficient sand to fill the voids, which is flushed into the interstices with water from a fire hose. Following this the sub-ballast is rolled with a 5- to 7-ton roller. The ties and rails are then laid, additional ballast is then added and the rails tamped up the remaining 2 inches to grade. The space between the ties is filled with broken rock, except that pockets are left under the rail, and for a width of 12 inches on either side, into which concrete is poured to form a foundation for the header blocks. These basalt header blocks are laid adjacent to the rails on a 1 to 3 dry sand and cement bed. The pavement base, where asphalt surface is used, is then poured to the required grade between these blocks, after which 1 to 1 cement grout is poured between the block joints, using a strip of canvas weighted with sand along the outer edges of the blocks to retain the grout until it is set. The asphalt paving, consisting generally of a 1½-inch thickness of binder and a 1½-inch thickness of asphalt topping, is then laid, after about 7 days. When the track work has been thus completed and before cars are operated, all joints are gone over with a Vixen plane and brought to a perfect surface. The rails, as in nearly all paved track construction, are laid with close joints, except that in special work ⅛-inch joints are specified.

The city has about ¾ of a mile of double track operated jointly with the Ocean Shore Railroad Company. This track is constructed under the same specifications, except that the rail is 141-pound section with flangeways for M. C. B. wheels. Freight cars of 100,000 pounds capacity are regularly handled over this piece of road, and so far no trouble has been experienced either in the track or in the adjacent header blocks and pav-

ing. There has been no pumping up of the header blocks, a common annoyance where a sufficient foundation is not provided for the blocks and care is not taken to keep water from penetrating the paving base. Mr. Eckart.

The Municipal lines cross a number of cable tracks and in a few instances trouble has been caused by the expansion of the rails closing the cable slots. To prevent this condition, which had been anticipated, struts were riveted to the under side of the rail bearing on the cable yokes and concrete blocks carrying the cable construction. Where the electric tracks are laid downhill from the cable crossing, these struts are generally omitted; in one instance, however, where two cable tracks were crossed a block apart on a grade, the struts at the foot of the grade have held and the expansion has forced the rail joints, tie rods and all up the hill through the concrete paving base with sufficient force to partially close the cable slot at the top of the hill. Standard slot widths are ¾ inch and the cable grips are ½ inch, allowing ¼ inch leeway. The remedy quickly applied was to restore the slot to its original width by burning with oxy-acetylene.

The author has not included in his paper any reference to the important subject of track special work. San Francisco has been installing throughout solid manganese special work, of double-web construction 9 inches deep, with flange bearing risers at intersections. These risers reduce the noise at crossings and increase the life of the special work materially, due to the reduction of shock. They have given rise to no trouble except where used in conjunction with the Ocean Shore tracks. Here a number of chipped wheel flanges in the 100,000-pound freight cars have been reported, but this Mr. Eckart believes to be due to taking these crossings at too high a speed.

The city has developed a standard specification for track special work covering the character of material, design, and limits of tolerance. All similar pieces are interchangeable in any and all layouts and the fishing sections are ground so that standard joint plates may be used throughout. This feature of interchangeability is very valuable in reducing the number of spares to be carried and facilitates maintenance.

The author refers to the use of manganese-steel rails. It would seem that where manganese rails are used, special attention should be paid to the bonding of these rails, inasmuch as the conductivity is only about one-fourth that of open-hearth steel rail and about one-fortieth that of copper, thus requiring a much larger area of contact for the bonds in order to keep the current density in the rails at the point of bond contact within reasonable limits. Compressed terminal bonds are not suitable for use in the manganese castings, owing to the practical impossibility of drilling the necessary holes, to overcome which difficulty resort has been made to casting plugs in the rail, which plugs must be quite large to prevent excessive current density. In the city's standard construction all bonding is carried clear around the manganese special work by copper cables, no attempt being made to bond the manganese. In addition to avoiding bonding trouble in the casting, it renders replacement of special work less dif-

Mr. Eckart. ficult. It would seem that with the use of any length of manganese rolled rail, it would be necessary to supplement the bonding of the rails with additional copper to secure sufficient capacity in the return circuit in order to decrease liability to electrolysis, which will occur whenever the potential gradient is excessive.

Paper No. 88

SIGNALS AND INTERLOCKING.

By

CHARLES HANSEL, M. Am. Soc. C. E.
New York, N. Y., U. S. A.

The International Engineering Congress held at Glasgow in September, 1901, was the last Congress which considered the subject assigned to the writer. During the deliberations at Glasgow, a paper by Mr. I. A. Timmis, M. Inst. C. E., entitled "Modern Practice in Railway Signaling" was read. The subject of Signals and Interlocking was treated broadly under two headings: First, the Westinghouse High-Pressure (Electro-Pneumatic) System; second, the Low-Pressure Pneumatic.

The intricacies of signaling and interlocking call for a vast number of parts; and, perhaps, no other branch of railway operation requires the accuracy of design, construction, installation and maintenance as is required by the various forms, styles and installations of block signal, power interlocking and manual interlocking.

The writer assumes that this Congress is not particularly interested in listening to a discourse on the principles and details of track circuits, automatic signals, power interlocking, and the like; but prefers, rather to be directed to the most important developments which have occurred in the art of signaling and interlocking since the last paper on this subject, which was printed in the Proceedings of the Congress at Glasgow in 1901.

After the practicable development of the automatic block system as installed on steam-operated railroads, came the development of track circuit methods, which provided for the use of the track circuit: thus the automatic block. On electrically-operated railroads, without such development the large

terminals and stretches of outlying track now operated electrically would still have to be operated by steam.

It is a matter of universal knowledge, that the track circuit as installed and used on steam railways for many years is the controlling factor in automatic block signaling and that, without such rail circuit, our present knowledge of the art of signaling is insufficient to provide an automatic block system of equal merit.

The installation and maintenance of the rail circuit on steam railroads is simple and inexpensive so long as the propulsion power of trains is the steam locomotive. The operation of trains by electric power by means of motor cars or motors requires the uninterrupted use of the rail for propulsion purposes; therefore, the problem of dividing the track into blocks —as is easily done where the motive power is self-contained and does not require a return current through the rails—at once becomes difficult, since it is necessary to employ two different currents using the same path; i. e., the rail or rails. The propulsion current must not be impeded, whereas the block signal rail circuit must be impeded so as to divide the track into blocks. Thus, while the impedance bond is necessary in order to cut off the block circuit, there must be no impedance offered to the propulsion circuit.

Since the majority of electric lines are operated on the direct-current principle, it was necessary to perfect a method of employing alternating current for signal track circuit where both track rails must be retained for propulsion purposes. To accomplish a rail circuit for block working on electric lines, impedance bonds are installed, for the same relative purpose as the ordinary insulated joints on steam-operated roads. These impedance bonds are now designed on simple and practical lines; although, when the subject was first broached to the electrical experts, it was not believed to be practicable by reason of the supposed necessity of design, which would provide an apparatus of such bulk and cost as to make it impracticable.

The development of the A. C. signal track circuit was accomplished primarily for the purpose of installing auto-

matic block signals on suburban electric railways; and the first reported notice of the satisfactory development of the A. C. track circuit appears in the notice to the stockholders of the Pneumatic Signal Company, November, 1902. At that time, the very important development of the New York Central Terminals at 42nd Street, New York, and the Pennsylvania Terminals in New York City, as now planned and operated, had not been contemplated; and, indeed, it would not have been practicable to operate such terminals by electric propulsion without the use of the A. C. track circuit, or rather the principles used and developed by the A. C. track circuit, in association with the impedance bond. Thus, the development of the A. C. signal track circuit marks an epoch in safe and economic railway operation.

UPPER QUADRANT SEMAPHORE SIGNAL.

As is well known, the art of signaling was first developed to a satisfactory stage in England, and the practices of English railways in respect to signaling and interlocking were generally adopted in the United States. As we look back upon the principles and the designs which govern the manufacture, installation and operation of the earlier signaling devices, we may well wonder why principles were adopted which now seem obviously incorrect and expensive.

The first semaphore signal indicated "safety" by the position of the arm below the horizontal. "Danger" was indicated by the horizontal position of the arm. In order to insure the signal arm going to the horizontal position in case of the breaking of connections between the operating power and the signal, it was necessary to counter-weight the arm; and this counterweight must be sufficient to overcome, not only the weight of the arm itself, but also any accumulation of ice and snow. Since the weight of ice and snow accumulating on an arm is considerable, it follows that the counter-weight necessary to insure the moving of the signal arm to the horizontal position is considerably greater than would be required if it were not necessary to provide for the conditions attendant upon ice and snow and weight of signal arm. With the excessive counter-

weight necessary to insure the movement of the signal to "danger" in case a connection broke, the power necessary to clear the signal is unduly augmented.

It is obvious that, if the indication for a clear signal is given by moving the arm above the horizontal, the necessity of the counter-weight will disappear and any accumulation of ice or snow on the signal arm would tend toward safety by causing the signal arm to fall from the upper quadrant to the horizontal position, or below. Thus, if the indication of safety is given by moving the signal arm to a position above the horizontal rather than below, as was, and is, the English practice, we not only secure a safer signal, but we materially reduce the cost of operating same; especially when the signal is automatic and operated by mechanical power.

All of the modern installations now being made in the United States have the upper quadrant semaphore signal. The earlier installations of this form of signal were on the Great Northern Railway in Minnesota, in 1907; on the Philadelphia, Baltimore and Washington Railroad at Media, Pa., in 1906; on the Washington Terminal at Washington, D. C. (where there are 201 semaphore signals), in 1907; on the St. Louis and San Francisco Railroad near Clathe, Kansas, in 1909; and on the Nickel Plate, at Griffith, Ind., in 1909.

The three-position automatic semaphore followed closely the perfection of the upper quadrant. While the indication above the horizontal for "clear" was not necessarily a part of the development of the three-position signal, the upper quadrant lends itself more satisfactorily to the three-position indication; and, while, in the opinion of many signal engineers, the development of the three-position indication is a very important step in the advancement of railway signaling, it does not mark an epoch as clearly as does the development of the upper quadrant indication.

The writer contended for years for the upper quadrant indication for the semaphore and took frequent occasion to publish papers on the subject in the technical press. It is interesting to note that in an editorial comment on one of these articles in which the writer urged the adoption of the upper

quadrant, the editor took occasion to express the opinion that it was not likely that the railroads would adopt the drastic suggestion of showing a clear signal by the indication above the horizontal rather than below, as was then the general practice.

AUTOMATIC TRAIN CONTROL.

The development and installation of automatic semaphore signal systems, while providing a visual system of signaling almost perfect in its operation, does not compel discipline nor provide against the failure of the trainmen to observe and act upon the indication of such semaphore signals. In the opinion of the writer, the next important development of the railway operation will be the perfecting of a suitable system of automatic train control.

To appreciate the influences that guide the actions of a locomotive driver, one must study the conditions from the cab of the locomotive; and it is probable that, if more people were familiar with these conditions, there would not be such a desire for speed at the expense of safety. It is not likely that any argument of this character will change the temperament of a nation, and we must, therefore, view the conditions as they exist, and endeavor to guard against the involuntary or inexplicable acts of the locomotive driver, who, while possessing keen intelligence and a desire to do his duty to the public and his employer, occasionally fails for reasons that, in many cases, he cannot himself explain.

Accidents have occurred, with horrifying results, where the railroads were equipped with as good a system of visual signals as is known to the art; and it was clearly proven that these signals were operative and indicated the exact condition of the block they governed. These accidents demonstrate that the locomotive driver must be protected against the time when he shall fail from mental or physical inability or from inattention; and it can hardly be expected that any human being will always do that which he ought to do.

It is possible to provide for the automatic control of trains by means of apparatus beyond the reach of the locomotive

driver, fixed at predetermined points on the permanent way so as to apply the air brakes in case the train attempts to pass when the signal is at ''danger''. Any such device should be considered in relation to the carrying of traffic safely without unnecessary interruption. No devices should be encouraged which would tend to remove the responsibility from the locomotive driver of observing visual or other signals, and it should only become automatically operative when the locomotive driver becomes, as it were, ''de-energized'', physically or mentally, or both. He should retain the control of his train at all times so long as he is ''energized'' and fit mentally and physically to perform the function of his post. He should be able to pass a signal at ''danger'', provided, however, there is no obstruction in the block or section of track it governs; or, in case he has a permissive card authorizing him to proceed by signal under control; or whenever he knows a signal is at ''danger'' because it is out of order; and there may be other conditions which might make it necessary for him to pass a signal at ''danger'' in order to protect his train. He should be able to hold the apparatus from operating automatically; but, in case he does so hold the apparatus from operating, such act should be recorded, as to time and frequency, in such a manner as to make a secret record beyond his control.

It is entirely practicable to give all of these results without interfering with the proper and independent action of the locomotive driver so long as he is competent to act. Such devices may be so arranged in connection with the locomotive as not to inconvenience the driver, and still provide against the time when he may fail to do that which he ought to do. There is, of course, a great diversity of opinion as to how far we should attempt to carry the automatic control of a train, and it may be that, in the opinion of some of the operating officials, it would only be necessary to automatically shut off the steam and give an audible signal in the cab; whereas, others might desire all of the functions above indicated. In any case, the automatic control should be used as an auxiliary to fixed signals and be governed by the condition of the block; in which case, it would protect the train against a false in-

dication of the signal, which sometimes shows "clear" when it should be at "danger".

By using the automatic control system as an auxiliary in the manner described, the equipment of each locomotive and block increases the unit of safety; and, even though only one locomotive be so equipped, we shall have taken a permanent forward step which will insure the control of that train just as surely as if all the locomotives were fitted; and all additional locomotives so equipped would add to the percentage of protection. It is evidently not necessary to have a definite percentage of all the locomotives equipped before we can secure the benefit of the apparatus, as in the case of the air-brake system.

Assuming that a railway thoroughly equipped with a semaphore block system has also added the proposed system of automatic control: the locomotive driver, instead of feeling that he is relieved from the responsibility of observing the visual signals as closely as heretofore, finds that he must use greater vigilance, because a record is made of every time he passes a home signal at "danger"; and, with the knowledge that such record will be in the hands of his superior each day, he will certainly hesitate to sacrifice safety to speed.

The failure of the automatic control system is not by any means as serious as the failure of the visual system, because it is only an auxiliary; and, as the engineer has to depend upon the indication given him by the visual system to advance or stop, there is nothing in the automatic control which authorizes him to advance.

Many engineers have been opposed to automatic block signals for the reason that there is no record of the failure to observe signals, as in the case of the manually-operated signals; and, consequently, it is impossible to discipline the enginemen. The automatic control of trains, with the apparatus making a secret and permanent record, would remove the objection to the automatic block system, and make it more complete and perfect than any other system now known.

The automatic control of trains will be found especially valuable when fog occurs, as it will provide an audible signal

in the cab, and control the train as well. This will obviate the necessity of torpedo signals, as in England.

Very little progress was made in England in the development of automatic control of trains until within recent years, except as an adjunct for safer working during fog. During the last few years, however, a number of accidents have occurred which have been entirely due to drivers over-running the signals, thereby directing attention to the need of an auxiliary to the visual signal system. A number of such auxiliary signals have been given a more or less extended trial by the Board of Trade officers who have more or less interested themselves in the matter, and they have said:

> "Our recommendation is that Railway Companies should be urged to carry out combined experiments with different systems of Cab Signaling and Automatic Control with the object of supplementing the present system of semaphore signaling".

There are at the present time two systems which have been extensively tried and adopted to a limited extent in England. The first is the Western System; the second, the Raven System. The former was first tried on an extensive scale on the Great Western Railway. It was inspected by the Board of Trade, and other provisional sanction was obtained for it to be used for a period of six months as a substitute for the semaphore distant signal. As a result of this test, the Board of Trade gave their full sanction of the apparatus, and the distant signals were permanently removed.

When we consider the extreme conservativeness of the inspectors of the Board of Trade, we must conclude that the apparatus was at least more perfect than the distant signal system which it displaced.

With the exception of the subways, where the automatic control of trains is in successful operation, there are, in the United States, no installations of automatic control of trains. None of the Continental railways is equipped with automatic control, though many experimental installations have been made.

Signal engineers and railway operating officials, generally, do not feel that the cab signal or automatic train con-

trol should necessarily supplant the visual or roadside signal as now installed under the general term "automatic block signals", but rather that these wayside signals should be supplemented by the cab signal and automatic control.

In railway signaling, there are recognized, well-established protective rules, to which appeal is made when measuring the utility or capacity of a signal system for promoting safety.

A large proportion of the inventions offered to provide an automatic stop are practically useless; another class of such inventions discloses the fact that their authors are entirely unfamiliar with the conditions to be met and the engineering rules to be observed.

In the art of signaling, the protective value of a proposed invention is determined in the first place upon whether or not the mode of action and the fundamental designs of the device satisfy certain engineering rules.

In the gradual development of the art of signaling, the requirements have become exacting, and have resulted in placing the question of the "survival of the fittest" authoritatively upon a scientific basis.

Railway operating officials, as also the Federal Government of the United States, now realize that it is practicable to provide a system of automatic train control, and the Railway Signal Association of the United States has promulgated a set of specifications, as follows:

REQUISITES OF INSTALLATION.

Note. These requisites are drawn for application in connection with a properly-installed block-signal or interlocking system.

1. The apparatus so constructed that the failure of any essential part will cause the application of the brakes.

2. The apparatus so constructed that it will automatically control the train in the event of failure by enginemen to observe signals or speed regulations.

3. The apparatus so constructed that it will control the train in the event of a failure of fixed signals to give proper indications.

4. The apparatus so constructed that proper operative relations between those parts along the roadway and those on the train will be assured under all conditions of speed. weather wear, oscillation and shock.

5. The train apparatus so constructed as to prevent the release of the brakes, after automatic application has been made, until the train has been brought to a stop, or the speed of the train has been reduced to a predetermined rate.

6. The train apparatus so constructed that when operated it will make an application of the brakes sufficient to stop or control the train within a predetermined distance.

7. The apparatus so constructed as not to interfere with the application of the brakes by the engineman's brake valve or the efficiency of the air-brake system.

8. The apparatus so constructed as to be operative when the engine is running forward or backward.

9. The apparatus so constructed that when two or more engines are coupled together, or a pusher is being used, the apparatus can be made effective on the engine only from which the brakes are controlled.

10. The apparatus so constructed as to be operative on trains moving only with the current of traffic.

11. The apparatus so constructed as to conform to the American Railway Association standard of clearances of rolling equipment and structures.

12. The apparatus so constructed as not to constitute a source of danger to employees or passengers, either in its installation or operation.

13. The apparatus so constructed as not to interfere with the means used for operating fixed signals.

Adjuncts.

The following may be used:

(A) **Cab Signal.** A signal located in the engine cab indicating a condition affecting the movement of the train and so constructed that the failure of any part directly controlling the signal will cause it to give the "stop" indication.

(B) **Detonating Signal Apparatus.** An apparatus located along the roadway and so constructed as to give an audible signal by means of a torpedo or other explosive cartridge.

(C) **Speed Indicator.**

(D) **Recording Device.** An apparatus located on the train and so constructed as to make a record of the operations of the automatic applications of the brakes and of the speeds of train, and such other records as may be desirable.

The perfecting of a system of cab signaling and automatic control of trains is a duty which should not be left to the unassisted efforts of the individual.

Governing powers have laid down rules and specifications for the ideal,—a goal for someone to achieve. This is not sufficient. The public interests demand that more speedy progress be made; and it seems reasonable to expect that the governing powers should join with the railroads, and offer such incentive as will stimulate practical work, and hasten the day when the traveling public will be more fully protected by the cab signal coordinated with the wayside signal and also the automatic control of trains.

DISCUSSION

Mr. H. J. Kennedy said that he had noticed that the upper quadrant signals are used in some places and he wanted to know if the absence of sleet here is the reason why the Southern Pacific Co. uses the lower quadrant type. He wished to ask why an automatic stop was not placed at the point of the last wreck on the Northwestern Pacific Railway. Mr. Kennedy.

Mr. L. M. Perrin,* Assoc. A. I. E. E., said that the wreck on the Northwestern Pacific Railway could have been prevented by the use of an automatic stop, but that the diversified traffic precluded an automatic stop at this point at present. Mr. Perrin.

On the Brooklyn Subway a system of cab signals has been installed instead of the fixed signals.

According to the latest Interstate Commerce Commission report 50% of the railways have block signal control, 15% automatic and 35% manual.

Mr. Paul J. Ost,** in answer to Mr. Kennedy's question as to why automatic stops were not used on the Northwestern Pacific, said so many kinds of equipment are in use there, that an automatic stop is out of the Mr. Ost.

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** Electrical Engineer, San Francisco, Calif.

Mr. Ost. question. Steam, electric and narrow-gauge equipment are run over the same roadbed, and they all have different clearances.

The upper quadrant has the advantage of three positions, which the lower quadrant does not have:—horizontal, denoting danger; inclined at 45 degrees upward, for caution; and vertical, to denote a clear track. The caution signal may be displayed by the semaphore arm that displays the danger signal; thus the one arm may be made to do the duty of both the distant and home signal. To the best of his knowledge the three positions in the lower quadrant are not as clearly defined as those in the upper quadrant.

Mr. Kennedy. **Mr. H. J. Kennedy** recalled that some years ago semaphore blades were constructed so that there were three positions in the lower quadrant—horizontal showing red, or danger; 45 degrees downward showing green, or caution; and clear down, white or proceed.

Mr. Ost. **Mr. Paul J. Ost**, in reply, stated that the proceed of the lower quadrant is not as clear as the proceed of the upper quadrant.

Mr. Simmons. **Mr. H. H. Simmons*** wished to state that the Chicago & Eastern Illinois have automatic stops working on their main line between Peoria and Danville, and this is a steam operated road.

* Chicago, Ill.

Paper No. 89

RAILWAY TERMINALS.

By

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This paper will deal principally with railway freight terminals.

The question of railway terminals may be discussed from many view-points: from the general organization of the terminal system, its general layout and methods of operation, down to the minute details of track layouts.

The theories on which assembly and classification yards, distribution yards, local delivery yards and their operation are based are very much the same throughout the country. It is true that each city and each terminal point has its own peculiar physical limitations, and the details of laying out a terminal system and its operation are largely controlled by local conditions. The precise methods of operation employed are not, in the judgment of the writer, of as great interest and importance as the general theory of terminal operation in this country.

In approaching a great center of industry and population, the railroads have generally planned their terminal layouts to provide for assembly, classification and holding yards outside of the congested district, for inter-communication with other railroads by belt lines or direct switching, and for distributing and receiving freight stations located at strategic points within the terminal district; and this latter includes facilities for the transfer of commodities between rail and water carriers, where this is part of the business of the terminal district.

The writer, therefore, has prepared a series of maps showing six of the important railroad and terminal centers of the United

States; these include New York, which is the principal manufacturing district of the country as well as the principal port for foreign commerce; Chicago, Buffalo and Cleveland, which are Lake Ports; St. Louis, which is distinctly a River Port; and New Orleans, which, while it is one hundred miles from the Gulf of Mexico, still may be considered a Gulf Port.

On these maps the railroads are brought out prominently in order to show the terminal arrangements; and street systems and other details usually found on maps of these cities have been largely omitted.

Before entering into a detailed statement of the terminal situation at these cities, it might be proper to discuss the relation of the railroad terminals to the railroad systems, and of the railroad terminals to the general economic conditions at these localities.

Unquestionably the most expensive parts of railroad systems are their terminals, both as to physical construction and as to operation, and this is especially so in the vicinity of and within large cities.

The capacity of a railroad for doing business is measured largely by the capacity of its terminals. It is usually a comparatively simple and inexpensive matter to add additional tracks to a railroad line. There are places, of course, where the contour of the country renders this expensive, and although most of the principal rivers are followed on both banks by railroad lines, yet it is almost always possible, with a reasonable expenditure, to increase the rail facilities by adding additional tracks. It is sometimes necessary to make a detour to accomplish these additional tracks, and it is sometimes necessary to enter into a general reorganization; but taking it as a general proposition, increasing the facilities of a railroad by adding additional tracks is not a difficult or expensive matter.

When, however, it comes to increasing the terminal facilities within large cities and terminal districts, the problem is a far more difficult one. There is the greater expense of right-of-way, the greater difficulty of separating the rail traffic from the vehicular and street traffic of the city, and the necessity of avoiding grade crossings with other lines. The most advantageous

locations for terminal facilities are already taken up by the railroads and transportation systems which have foreseen the growth of the territory and the importance of advantageous locations, and have pre-empted the most available of them.

The time has passed when the railroads are allowed to cut rates against each other, the tariffs having been fixed by the Interstate Commerce Commission. In the past the railroads have been able to hold out inducements to shippers by granting special privileges in the matter of switching and spotting of cars, in rebates and in other ways. This now cannot lawfully be done, nor can special privileges in the way of rebates be made by any carrier, but equal services must be extended to all. The competition for business, therefore, between the railroads at important points is now limited to the competition for the best terminal facilities, in order that the shipper may most conveniently and quickly deliver and receive his freight at the freight stations, and in order that the quickest freight movement may be provided.

This competition by the railroads for terminal facilities is in many ways advantageous to the communities, for it is through this competition that quicker deliveries can be made and that a shipper may receive or deliver his freight from the freight station with greater ease and consequently less cost, but there is another feature of this competition which may not be considered to be to the public advantage.

In many places the railroads, in order to provide better terminal facilities than their rivals, have done so at seemingly unwarranted expense, not only in the installation but also in the operation of their terminals. This expense in many cases is out of proportion to the services rendered, but with a great railroad system it is possible to absorb these heavy terminal costs by distributing them over the great mileage of their systems.

The railroad companies have been seeking from the Interstate Commerce Commission the right to increase their rates, and as an argument in support of this contention, they state that higher rates are necessary in order to take care of the higher cost of doing business. There seems but little doubt that the costs to the railroads have become higher, but perhaps these increased costs are due largely to increased terminal costs, and

this, to a large extent, may be due to the rivalries which exist between the railroads to create more convenient terminal arrangements so as to draw business to their lines. This means that the public is asked to pay for the expensive individual terminal arrangements that the rivalries of the railroad companies have created.

A mere glance at the maps contained in this report will show the extent to which the individual railroads have gone to create a multiplicity of private terminal facilities.

The solution of this difficulty appears to be in the reduction of individual railroad terminal installation and in the establishment of joint facilities in large cities through which to handle the business of all the railroads within the terminal district.

In New York Harbor, for instance, there are nine separate and individual railroads with their tide-water terminals in the New Jersey portion of the harbor. Each of these railroads performs its individual lighterage service and each of them has established its individual freight terminals, throughout the harbor.

This individual railroad operation in New York necessitates the movement of cars, lightly loaded, the duplication of services and high rentals for individual terminal stations, all of which adds to the cost of the freight movement; but the fact that competition is restricted to these terminal services has caused the more progressive and far-sighted railroad companies to secure all they have been able of the available locations, with a view of not only serving their own immediate and growing needs, but also of preventing their competitors and rivals from securing additional facilities through which to compete with them.

The rivalries of the railroads have made it difficult to arrange for the establishment of joint terminal systems and have made it necessary, particularly in New York, to devote much valuable land, especially on the waterfront, to railroad business, where it is much needed for other purposes and for shipping. The growth of business and the present expense of individual terminal services, will, it seems, necessitate the organization and operation of a more economical and efficient joint terminal service.

Chicago, appreciating this difficulty, has been striving to effect a better freight terminal system; Buffalo is now undertaking a system of joint railroad operation. In St. Louis and in Cleveland they see the necessity for some less expensive joint operation.

New Orleans, probably in advance of any city in this country, has progressed far in perfecting its terminal organization. The water-front is largely operated as a joint public utility, and in addition the belt line railroad is publicly operated at cheap rates, where all the railroads are served on an equal basis.

San Francisco has done much in establishing a public belt line; Philadelphia is working for this and for joint railroad services, as are Boston and Baltimore and many of the other cities.

There seems to be a realization in this country at this time of the necessity of discarding the costly individual private terminal operations in large cities, and of substituting therefor a joint terminal system under a certain degree of public supervision through which the shippers can be properly served with the sacrifice of a minimum amount of valuable property, and with a cutting down of the costs to the carriers as well as to the shippers.

The following more or less detailed descriptions of the terminal situations at the cities above mentioned will serve to indicate the amount of individual operation that has grown up, and will also serve to show, particularly in the case of Chicago and of New York, the necessity of abandoning this expensive individual operation in favor of a more economic joint terminal system.

NEW YORK TERMINAL SITUATION.

The terminal situation at New York is quite different from that of any of the other large cities in the country. The port of New York is divided by water into five principal sub-divisions: The Borough of the Bronx in New York City on the mainland to the north; the Boroughs of Brooklyn and Queens in New York City on the mainland to the east; the Borough of Richmond or Staten Island in New York to the south; the Borough of Manhattan, separated from the mainland by the Harlem River, the East River and the Hudson River in the central portion of the

harbor; and the New Jersey district, comprising many municipalities on the mainland to the west.

The principal railroads from the south, the west and the northwest have their tide-water terminals in the New Jersey district without physical connections for freight service to the New York portion of the harbor. The Borough of Manhattan has rail connection only with the New York Central and Hudson River Railroad, the Borough of the Bronx only with the New York Central and the Hudson River Railroad, and the New Haven Railroad, the Boroughs of Brooklyn and Queens only with the Long Island Railroad, and the Borough of Richmond only with the Baltimore and Ohio Railroad. This refers of course to freight service.

In the New Jersey district are the terminals of the Central Railroad Company of New Jersey; the Delaware and Hudson Railroad; the Delaware, Lackawanna and Western Railroad; the Pennsylvania Railroad; the Lehigh Valley; the Erie Railroad; the New York, Ontario and Western Railroad; the Philadelphia and Reading Railroad; the West Shore Railroad, including the New York Central lines west of Buffalo; and of these railroads in New Jersey, all have physical connections with each other.

On account of these tide-water terminals in New Jersey, a great part of the best of the water-front in the New Jersey portion of New York Harbor is occupied as railroad terminals for lighterage of freight to and from the other portions of the harbor; and in an examination made during July, 1913, it was found that there were 71 foreign steamship lines with regular sailings to foreign ports located in the New York portion of the harbor, while only 6 were located in the New Jersey portion of the harbor. This is, of course, an unnatural state of affairs and one that is only made possible by the free lighterage services which the railroads perform throughout the harbor.

There is no general terminal organization in New York Harbor, although there are four terminal companies which perform certain local service.

Each of the railroads conducts its own separate lighterage system, and the rivalries of the railroads, which are very keen at the port of New York, have created a great number of individual

terminals to which the services performed are only done at great expense.

It will be interesting perhaps to quote from the New Jersey Harbor Commission's Fourth Preliminary Report, of which the writer was the principal author, the following concerning the railroad and steamship situation in New York Harbor.

"New York Harbor is the great point of trans-shipment between rail and water carriers, and this separation of the railroad terminals and the steamship terminals by bodies of water, necessitates a large amount of lighterage which is expensive and wasteful.

"Method of Conducting Railroad Business.

"The railroad business on the New Jersey side of the harbor may be divided into three classes:

1. Shipment and receipt of freight to and from Manhattan Island and the other boroughs in New York.

2. Shipment and receipt of freight to and from ships.

3. The transfer of railroad cars between the railroads terminating in New Jersey and the railroads terminating in New York.

"Considering first the business with Manhattan, practically no freight is sent on to Manhattan Island for trans-shipment, but all freight sent there is for consumption or fabrication on the Island itself.

"The statement is frequently made that New York Harbor may be divided into three classes:
applies to the Hudson River water-front in lower Manhattan, and probably nowhere is there greater congestion at terminals than in this district. It has been possible to get high rentals for piers in this district and it has been the policy of the City of New York to execute long term leases, many of them to railroad companies, which return to the city a large revenue. A large portion of the food supply of Manhattan is brought to the piers on the West Side, by the railroad companies from New Jersey, and owing to the congestion and generally inadequate terminal arrangements, there is a very considerable waste of food products and perishable materials.

"This business is of the first importance to the City of New York and to Manhattan Island. Various plans for relief have

been proposed, various commissions have been organized, and have reported plans for relief, and a very general study has been made, to provide a plan whereby delays in the handling of perishable freight could be reduced, and better terminal arrangements could be had that would tend to decrease the terminal costs, and at the same time to better the quality of the food product as received by the consumer and to decrease its costs.

"A considerable amount of freight is brought from the New Jersey railroads to Manhattan for fabrication. Manhattan has grown as the business and financial center of the country, and generally in the plans proposed, it has not been the purpose to draw manufacturing to the island but rather to encourage it to settle in the outlying boroughs. The large amount of manufacturing which is now done on Manhattan and the large population on the East Side, skilled in certain light manufacturing, make it necessary to provide for a considerable amount of manufacturing to be done on Manhattan; and in any plan for reorganization, it is necessary to provide for the economical receipt and distribution of raw materials and for sending out the finished product. The occupation of the westerly Manhattan water-front is shown in the following table taken from a paper presented to the American Society of Civil Engineers, February 21, 1912, entitled "The Problem of the Lower West Side Manhattan Waterfront of the Port of New York", by B. F. Cresson, Jr., M. Am. Soc. C. E.

"BUSINESS INTERESTS USING THE NEW YORK WATER-FRONT.

	From north side of Pier new 1 to 125 ft. south of Pier new 48, 11,780 feet = 2.23 miles	From north side of Pier new 1 to north side of 30th St., 20,658 ft. = 3.91 miles
Transatlantic steamships	1.4%	17.5%
Coastwise steamships	15.6%	23.3%
Railroads	47.9%	30.8%
Hudson River boats	5.3%	3.0%
Sound steamers	10.0%	5.7%
Ferries	9.5%	7.8%
Open wharfage	4.3%	3.9%
Miscellaneous, coal, ice, etc.	5.8%	6.9%
Recreation piers	0.2%	0.1%

"The above table shows the large amount of water-front which is given over to the railroad companies for their present use, and as the business with the railroads in Manhattan is increasing at the rate of from four to eight per cent per annum it is only a question of time when either better methods must be employed and a more economic use made of the water-front, or else the railroad occupation must be extended; this can only be done by excluding the steamship business more and more; the railroad business with Manhattan is of greater importance to the city than is the steamship business.

"The method of conducting the railroad business is usually as follows and this applies to freight:

"Trains are brought from the west and south to the railroad yards on the New Jersey shore where the freight is separated for the various terminals in and about the harbor. Cars containing freight for individual terminals are placed on car floats and towed across the river into the slips between the piers, awaiting the calling of the consignee. A certain time for storage must be allowed in order to give the consignee time to arrange for taking the freight away, but if the freight is not removed within a certain time the railroad companies send it to storage and charge the consignee with the expenses attendant thereto. The inbound freight to Manhattan is therefore handled on the piers.

"The outbound freight for the New Jersey railroads is delivered to the bulkheads and bulkhead sheds in Manhattan by truck during the day, but principally in the afternoon; the trains on the floats are not usually sent out until the evening and the truckman naturally wishes to hold his truck until he can have it fully loaded. Usually the same time of delivery at destination can be made, if the truck is on line at the bulkhead any time in the day prior to 4:30 P. M.; and the railroad company usually receives freight from all trucks which are on line waiting to make delivery, at or before 4:30 P. M.; there may be some exceptions to this but it is the usual practice.

"While the congestion of freight on the piers and bulkheads is also very great, it is this congestion of trucks and the delays incident thereto that cause the excessive terminal costs. It has been stated that it costs a merchant in Manhattan more to get his freight to and from the railroad piers than the amount he

pays to the railroad companies for transporting that freight from the piers to almost any part of the country.

"The freight in the bulkhead sheds is loaded onto the cars standing on the car floats in the slips. An effort is made to do as much classification of freight on the car-floats as possible, and as many cars are usually brought over as can be accommodated in the slips, in order that as many points of destination may be provided for as possible. The car-floats are towed across the river in the afternoon and evening on a regular schedule and the cars are then taken to the classification yards where any re-classification is done that is necessary, and trains are made up to go out on a regular evening schedule.

"The competition between the railroads, which at one time existed as to rates, has been eliminated; practically the only competition remaining is at the terminals where inducements are made to encourage shipment by providing better facilities for the receipt and distribution of freight, and by making more rapid delivery at destination.

"The railroad cars crossing the river on floats for this business are loaded only to an average of about eight tons each, and some idea of the amount of waterfront on Manhattan which is used in this manner, can be gotten when it is known that 1500 to 2000 railroad cars on car-floats occupy this waterfront every day.

"The business which the railroad companies do with the ships is conducted in another manner from that described above. Practically all of the freight passing between the railroads and the ships is unloaded from cars at the railroad yards in New Jersey on to lighters which are then towed alongside of the ships and the freight loaded directly into the ships, or the lighters are placed alongside of steamship piers where the freight is discharged to the piers for storage until such time as it can be loaded into the ships. In the case of inbound freight the reverse process is employed. In no case, as far as can be observed, is it the general practice to take railroad cars on floats alongside of ships for direct loading and unloading, except in the banana trade, where it is done to a limited extent.

"The transfer of railroad cars between the New Jersey railroads and the New England railroads is done by car-floats, and

as referred to in Appendix "E" which is a general description of the business layout of the harbor, a number of cars are transferred on car-floats to the terminal companies operating in the harbor.

"There are some features in the railroad situation in New York Harbor which are of special interest to the business community. In the first place, there is a "Differential" rate against New York and favoring neighboring seaports—this is a matter which concerns the port as a whole; and secondly, there is the system of "free lighterage" about the harbor, which concerns the various districts in the harbor."

Quoting still from this report concerning the plans proposed for the organization of terminal facilities about New York Harbor the following appears:

"There have been plans proposed from time to time in the past, for extensive terminal improvements in New York Harbor. It may be said that the facilities in the harbor have been a growth along lines of least resistance, rather than along the lines of a carefully thought out plan of general harbor development.

"As it has been stated before, many of the piers in New York Harbor were laid out at the time when the principal business was carried on by sailing ships, by canal boats and small steam and sailing craft, and there has not been any direct connection made between the shipping piers and the railroads, for the direct transfer of cargo.

"As long as there was plenty of room for the construction of additional piers whenever they were required, the situation was comparatively simple as regards providing berths, but when, in certain sections of the harbor great congestion developed, and when applications accumulated for steamship and railroad interests for accommodations in a particular section of the harbor, signifying their willingness to pay high rentals, then the situation became difficult.

"The real difficulty in the situation lies in the fact that by reason of the lack of any modern terminal arrangements, there is conducted on the river side of West Street and the Marginal Way, all of the business, all of the trans-shipment, and all of the freight handling that is carried on at the principal terminals for

the transatlantic passenger service, the principal terminals of the coastwise steamship business, the principal terminals of the New Jersey railroad systems (which latter have established a floating railroad yard in this water-front at which practically all of the food supply of Manhattan is discharged) and the principal terminals of the New England Steamship Companies and the Hudson River steamboat companies. In addition to these there are the ferry terminals of the New Jersey railroads; two for the Pennsylvania Railroad, two for the Central Railroad Company of New Jersey, two for the Erie Railroad, three for the Lackawanna Railroad, and two for the West Shore Railroad.

"All of this business is jammed together on this water-front and on the water-front side of this street, with but little relation between the piers, with no facilities for handling freight except hand trucks, and with no place to handle freight except on the piers, in the bulkhead sheds, and on the Marginal Way.

"The solution of the problem toward which practically all of the plans advocated have aimed, is to provide a means whereby the railroad cars of the New Jersey roads could be discharged and loaded, back from the water-front. Various methods of accomplishing this have been proposed, but the majority of them have advocated a marginal railroad along West Street and the Marginal Way on the surface, as a subway, or as an elevated structure, to deliver cars into terminals on the easterly side of West Street.

"A plan advocated by Hon. Calvin Tomkins, when Commissioner of Docks, City of New York, proposed the establishment of a general classification yard on the Hackensack meadows west of the Palisades to which all the New Jersey railroads would have access. From this yard by tunnels for standard rolling stock, a connection was made under the Palisades and the Hudson River to a marginal elevated railroad along the Marginal Way, extending from the 60th Street Yard of the New York Central Railroad as far south as Courtlandt Street, the tunnels to cross the river opposite 57th Street and connect with the elevated structure at about 39th Street.

"From this elevated railroad structure sidings were contemplated leading to terminal buildings on the easterly side of West Street, where trucks could receive and deliver freight with much

less congestion than now exists at the terminals on the water front.

"By means of this elevated railroad structure the unpopular surface tracks of the New York Central Railroad would be eliminated, and that railroad would have access to and the same rights on the structure as the New Jersey railroads. The purpose of this marginal railroad, which was to be built as a city enterprise, was to establish better terminal facilities on the practically unused lands on the easterly side of West Street and by attracting business to these terminals to join in the operation of this general terminal system and gradually give up their terminals on the water-front. By releasing this water-front from railroad occupation it could be devoted to steamship purposes.

"At the present time the easterly side of West Street is practically unused and the buildings are mostly one-, two- and three-story structures and devoted to lodging houses and cheap shops. The westerly side of this street, however, is probably the most intensively used of any section of the city. The easterly side of West Street is now cut off from the water-front by the Marginal Way and by connecting it by means of the elevated railroad with the rails of the New Jersey railroad systems, a considerable portion of the business now done on the river side of the street could be transferred to the easterly side.

"By this means the business which the railroads do with the Island which does not require the water-front, could be separated from the business which the ships do with the Island, which does require the water-front.

"The New York Central Railroad agreed to construct an elevated railroad at its own expense to take the place of its surface tracks, thus indicating the practicability of its operation. A private corporation has made an offer to construct tunnels under the Hudson River from a joint railroad yard in New Jersey to a subway along the Marginal Way, using the overhead space in the Marginal Way for storage, warehousing and factory purposes.

"Practically all of these plans contemplate joint operation and a general terminal system of some sort in New Jersey, and the adoption of such a plan would have a very important bearing upon the situation on the New Jersey shore opposite Manhattan. This frontage is now extensively used for loading rail-

road cars on to car-floats for transfer to Manhattan by water. If this transfer could be made by an all-rail connection through tunnels or over bridges the extensive railroad occupation on the New Jersey side that now exists would be relieved, and it would be possible to rescue some of this water-front and develop it for the purposes of modern marine commerce, which would be splendidly served by reason of the existing railroad connection. All efforts to bring about joint operation of the railroads on the westerly side of Manhattan have so far failed, and the city authorities have also failed to come to any decision on a plan. Applications for accommodations here cannot be granted and carriers must either seek accommodations in some other part of the harbor or accept facilities which our neighboring ports are willing to give practically free of charge. The law of supply and demand will encourage the railroad companies having extensive holdings in New Jersey to reorganize and put to better use their valuable frontage to attract commerce which is willing to pay high rentals for accommodations in New York Harbor."

There have been various plans for belt line railroads proposed, and among them the plan proposed by Mr. Irving T. Bush, President of the Bush Terminal Company, is of great interest. This plan is described in the above mentioned report as follows:

"The Bush plan contemplates a general clearing house for railroad business to be located on the "Jersey Flats" between Greenville and Constable Point; to receive their freight in any form or classification, for any railroad or destination, and to classify and assemble in a yard located there, freight for any railroad or any destination. From this yard a four-track railroad is projected extending back of Newark and the Oranges, back of Paterson, and coming near the Hudson River somewhere above Tenafly. This railroad is planned to make connections with all of the New Jersey railroads back from the congested district, and the railroad itself would constitute a valuable industrial line.

"Under this general plan it would be possible to establish a general freight station, for instance on Staten Island, where freight could be received for any railroad and for any point on any railroad, and this freight could be shipped out each day. Similar terminals could be established in all other parts of the

harbor and mixed freight delivered at them could be floated to this clearing house yard on the "Jersey Flats" for separation and classification. In connection with this there could also be established a general lighterage service for railroad freight with ships and also a land delivery system. The possibilities of such a plan as contemplated by Mr. Bush are difficult to appreciate."

The map prepared will give some idea of the great number of individual terminals and freight yards about New York Harbor and even its cursory inspection would lead one to believe that much wasted movement could be saved through a joint terminal organization and much property now used by individual railroads might be saved for more advantageous purposes.

There is probably no portion in the United States where favorably located lands are so much in demand, and a general terminal organization in New York will release not only a valuable portion of the water-front, but also lands back from the water-front.

CHICAGO RAILROAD SITUATION.

Chicago is the terminus of 24 trunk lines, one not being open yet for passenger service.

Several of these have more than one branch. The Chicago and Northwestern has four; the Chicago, Milwaukee and St. Paul, the Illinois Central and the Wabash each have two; the New York Central and Pennsylvania have two each, under different names. Six passenger terminals, each with freight houses adjacent, accommodate these trunk lines. Two railroads, the Baltimore & Ohio, Chicago Terminal Railroad and the Chicago and Western Indiana Railroad, located almost entirely within the city limits, give many of the lines their entrance to freight houses and passenger terminals. The former brings four railroads to the Grand Central Station; the latter brings seven to the Dearborn Station and operates a suburban service of its own. All depend on the Baltimore and Ohio, Chicago Terminal Railroad and Chicago and Western Indiana Railroad to reach their downtown freight houses.

The Union Passenger Station west of the river is used by five trunk lines without a terminal railroad. The freight houses are within a mile of the station.

The Central Station on the lake front at 12th Street accommodates three lines, the freight houses being about $1\frac{1}{4}$ miles farther in on the lake front near the mouth of the river.

The La Salle Street Station, with freight houses near by, is used by three lines.

The Chicago and Northwestern occupies a separate terminal station, freight houses being located to the north, east and west within a mile of the station.

The accompanying map shows 118 yards of various sizes used for freight purposes, of which 26 are receiving or break-up yards. This includes the Chicago Clearing Yard, connecting the inner two belt lines. In addition, the hatched portion of the map shows an area almost covered with smaller yards, freight houses and passenger stations belonging to the various lines.

Freight interchange is effected by means of five belt lines, three in or near the city limits, one about 25 or 30 miles out, and another, as yet incomplete, a little beyond. There are also about a dozen small independent railroads in or near the city which perform transfer service.

The Chicago River, with its many slips and canals, the Calumet River and Indiana Harbor are used as terminals for water-borne traffic. The only comprehensive system of interchange of rail and water traffic is provided by the Chicago River and Indiana Railway. The water-front, except street ends, parks, etc., is controlled by railroads, steamship lines, grain, coal and lumber companies, etc.

Belt and Terminal Railroads.

The Belt Railway of Chicago is the inner line running from South Chicago to Cragin and connecting with all trunk lines for freight transfer. Under the same management is the Chicago and Western Indiana Railroad, a line with one branch, operating a suburban service and giving seven other railroads entrance to the Dearborn Station and neighboring freight houses. The C. & W. I. R. R. and Belt Railway has some ten yards, including the Chicago Clearing Yard.

The Indiana Harbor Belt Railroad line is four or five miles farther out and also connects all trunk lines. It has a regular fast freight schedule. There is a live-stock yard at West Hammond, an icing yard at Blue Island, a large yard at Gibson, and

smaller yards. It is linked with the Belt Railway through the Chicago Clearing Yard.

The Baltimore and Ohio Chicago Terminal Railroad parallels the I. H. B. R. R. south of the city, and uses the same line to the west, with an extension toward Mayfair from Franklin Park. It has branches north and south from Blue Island. The former again branches west to Forest Park with a large loop, and east to the Grand Central Station, serving the railroads which use that terminal. There are some eight yards.

The Elgin, Joliet and Eastern Railway extends from Waukegan, Wis., through Joliet to Porter, Ind., a distance of 130 miles, with branches to Aurora, South Wilmington and South Chicago. The road is for freight service only, has icing facilities at Joliet and docks at Waukegan and South Chicago. It connects all trunk lines.

The Chicago, Milwaukee and Gary Railway has a belt line which is projected to extend from Milwaukee to Gary. At present about 120 miles are operated between Rockford via De Kalb and Joliet to Delmar on the Chicago, Terre Haute and Southeastern Railway and connect most of the railroads south and west of Chicago.

Independent Connecting Railroads.

These connect with all lines either directly or by the Belt Railways. The Chicago Junction Railroad operates 145 miles of track around the stock yards and eastward to the I. C. R. R. on the lake-front, connecting with many lines directly.

The Chicago River and Indiana Railroad furnishes a good rail and water transfer system. It has 50 miles of track, including a 500-car yard on the South Fork near the stock yards, a water-front terminal warehouse and an 8-car transfer barge plying between it and warehouses at Lake and Fulton Streets.

The Chicago Heights Terminal Transfer Co. has 38 miles of switching track near Chicago Heights.

The Chicago and Illinois Western R. R., projected to Joliet, operates 17 miles of track between Willow Springs and Hawthorne, connecting with 17 railroads.

The Pullman Railroad operates 17 miles of track near Pullman and connects directly with seven railroads.

The Chicago, West Pullman and Southern Railroad operates 28 miles of track about Pullman and Irondale, connecting with 13 railroads.

The Chicago Short Line Co. operates 15½ miles of track near South Chicago, connecting with eight railroads directly.

The Illinois Northern Railway runs from Elsdon to 26th Street and Western Avenue, one mile, connecting with sixteen railroads.

The Chicago and Calumet River Railroad operates 3½ miles of track near Hegewisch connecting with eleven railroads.

The Manufacturers' Junction Railroad extends along the I. C. tracks near Hawthorne, from 16th to 34th Streets, 1¼ miles, and connects with five railroads.

The Calumet, Hammond and Southeastern Railroad operates eight miles of track at South Chicago and connects with two railroads.

Freight Tunnels in Business District.

About 60 miles of tunnels exist under the streets, connecting directly with warehouses, wholesale establishments, etc., with public stations for receiving freight and with the freight houses of some of the trunk lines. The cars are small, the service being intended as a substitute for trucking. Owing to lack of connection with a clearing yard or union package freight clearing house, the operations at present are confined to incidental downtown business.

"The Chicago tunnel has several objects, which, if the plans of its builders had matured would have made the tunnel property today a unique and immensely useful auxiliary transportation and transmission plant". (Arnold Report, p. 103.)

Trunk Lines.

These are mentioned after the belt and terminal lines for convenience, as many of them depend on the latter for their entrance to the city.

From the east, The Baltimore and Ohio R. R. runs along the lake shore, and formerly continued as far as the old I. C. R. R. station near the mouth of the river, using the I. C. R. R. tracks. The present entrance over the B. & O. C. T. requires a diversion of seven or eight miles. The old line, now a spur, has three yards. There is a freight house at Illinois

and Kingsbury Street, and others near the passenger terminal, the Grand Central Station.

The Pere Marquette Railroad comes in over the B. & O. S. W. and reaches the Grand Central Station and its freight houses by way of South Chicago and 63rd Street.

The Lake Shore and Michigan Southern Railway, the principal N. Y. C. line to Chicago, is the oldest line from the east and has a direct entrance to its terminal, the La Salle Street Station, and the freight houses near by. There are eight or nine yards.

The Michigan Central R. R. joins the Illinois Central at Kensington, has its passenger terminal with that road at 12th Street on the lake-front and its freight houses near the mouth of the river. It has a couple of large yards, also, an extension to the steel manufacturing district of Joliet west of Chicago.

The Cleveland, Cincinnati, Chicago and St. Louis Railway follows the I. C. R. R. line from Kankakee to Chicago and uses the lake-front station.

The Pennsylvania main line to Chicago is the Pittsburg, Fort Wayne and Chicago Railway, which has a direct entrance to the Union Passenger Station. It has four yards. The other Pennsylvania line, the Pittsburg, Cincinnati, Chicago and St. Louis Railroad (Pan Handle) enters the same station at the other end after a detour of three or four miles. It also has four yards. The two roads are joined by the two small Pennsylvania lines, the Englewood Connecting Railway at 58th Street and the South Chicago and Southern, which has several lines through the industrial district around the Calumet River.

The Wabash Railroad has lines from both east and west; both reach the Dearborn Station and Wabash freight houses by the C. & W. I. R. R. It has two yards.

The New York, Chicago and St. Louis Railroad (Nickel Plate) passing through Hammond, joins the L. S. & M. S. Railway at Grand Crossing and follows it to the La Salle St. Terminal Station, near which it has freight houses. There is one large yard.

The Erie Railroad comes in from Hammond to its freight houses and the Dearborn Station over the C. & W.I.R.R. It has two yards.

The Chesapeake and Ohio of Indiana follows the same course as the Erie from Hammond, where it has a yard.

The Grand Trunk Western Railway coming from the east enters at the southwest corner of the city and running eastward four miles connects with the C. & W.I.R.R. at 47th Street, using it to reach its freight houses and the Dearborn Station. It has a couple of yards.

From the south: The Chicago, Indiana and Southern Railway (N.Y.C.) connects with the L.S. & M.S. Railway at Indiana Harbor.

The Chicago, Indianapolis and Louisville Railway (Monon Route) uses the C. & W.I.R.R. from Hammond to its freight houses and the Dearborn Station. It has a couple of yards near Hammond.

The Chicago, Terre Haute and Southeastern Railway has not yet established a passenger service but will come into the Grand Central Station via the B. & O.C.T.R.R. through Chicago Heights.

The Chicago and Eastern Illinois, which has a receiving yard south of Dolton, enters from that point over the C. & W. I. R. R. and uses the Dearborn Station. The freight houses are near it.

The Illinois Central Railroad has two separate branches from the south and west. The southern branch reaches the lake shore at 50th Street and continues to 12th Street, its passenger terminal, and its freight houses at South Water Street. There is a yard between the two, and three yards farther out. This line has three branches in the city: one from Kensington to Blue Island, one from Kensington to the State line near Hammond and one from Brookdale to South Chicago.

The western branch, with a yard at Hawthorn, joins the other line at 16th Street on the lake front. It has a branch to Forest Park.

The Chicago, Rock Island and Pacific Railway, entering through Blue Island, connects with the L.S. & M.S. Railway at Englewood and follows that line to its freight houses and the La Salle Street Station. There are four yards and branches to Brainerd Junction and South Chicago.

The Chicago and Alton Railroad follows the south bank of

the Illinois and Michigan Canal and of the South Branch to a junction with the P.F.W. & C. Railway, along which it goes to its freight houses and the Union Station. It has four yards.

The Atchison, Topeka and Santa Fe Railway is nearly parallel and close to the C. & A. R. R. It joins the C. & W. I. R. R. at 16th Street and reaches the Dearborn Station and its freight houses. It has yards at Corwith and 18th Street.

The Chicago, Burlington and Quincy Railroad has yards at Hawthorn and Western Avenue. It joins the P.F.W. & C. Railway at 16th Street, and uses the Union Station. The freight houses extend as far west as 16th and Jefferson Streets.

There is a loop along the south branch of the river, with spurs between the many canals or slips on which the lumber yards and industries of that district are located.

The Chicago Great Western Railroad joins the B. & O.C. T.R.R. at Forest Park and uses that line to its freight houses and the Grand Central Station. Its Chicago transfer yard is on the B. & O.C.T.R.R. west of the Belt Railway.

The Chicago and Northwestern Railway has four branches. That from the west, the oldest railroad in Chicago, runs across the city and along the north side of the river to its mouth. The branches from the northwest and north join at Mayfair and Clybourn Junction and meet the first near the new passenger station located on an extension to the south. The branches are all connected by cross lines in or near the city. There is a very large yard at Proviso and seven others.

The Chicago, Milwaukee and St. Paul has two important branches and a short branch. The former join at Pacific Junction and have a cross line to the short branch. There are four large yards. The passenger terminal is the Union Station and the freight houses are north and west of that station, except one at 15th and Jefferson Streets. There are four large yards.

The Minneapolis, St. Paul and Sault Ste. Marie (Wisconsin Central) joins the B. & O.C.T.R.R. at Forest Park and uses it to the Grand Central Station. It has a large freight terminal at 12th and Canal Streets and a yard at Kolze.

Rail and Water Connections.

Chicago has three harbors in use, the Chicago River, the Calumet River and the Indiana Harbor Canal. In the Chicago

River 20 lines of steamers, with 84 vessels, have their terminals. Each line has its dock or warehouse for local city freight.

The vessels go to the Chicago River and Indiana Railroad Company's dock on the South Fork to receive and deliver freight carried by the western railroads. There are also two lighterage companies, operating three lighters which handled about 200,000 tons in 1911. They connect about 25 industries having docks on the Chicago River with the railroads.

Grain Elevators. On the Chicago and Calumet Rivers 23 of these, with a capacity of 32,300,000 bushels, shipped by water in 1911, 78,850,000 bushels, the receipts by water being small.

General Merchandise. A terminal warehouse at the mouth of the Chicago River occupies 1350 feet of dock, and handles through and local freight by rail, water and lighterage.

Lumber. Twenty-six companies received 1,475,000 tons by water in 1911, with no shipments by water. 16 yards located on the river neither receive nor ship by water.

BUFFALO RAILROAD SITUATION.

The 15 trunk lines enter in three groups. From the east, in a strip 1¼ miles wide, come the N.Y.C. & H.R.R.R., the West Shore R.R., the D.L. & W.R.R., the Erie R.R., and the L.V.R.R.

From the south, in a strip ¼ mile wide, come the L.S. & M.S.Ry., the N.Y.C. & St.L.R.R., the P.R.R., Buffalo Division, the Buffalo, Rochester and Pittsburgh Railway, the Buffalo and Susquehanna Railroad, and the Erie Railroad (Buffalo Division).

From Canada on the west, across the International Bridge, come the Grand Trunk Railway, the Wabash Railroad and the Michigan Central Railroad, over whose tracks the Toronto, Hamilton and Buffalo and the Pere Marquette (freight only) reach Buffalo.

The Buffalo and Alleghany Valley Division of the Pennsylvania Railroad enters from the southeast.

Passenger Terminals.

There are three: the Union Station is used by 10 lines, the N.Y.C. & H.R.R.R., the L.S. & M.S.Ry., the B. & S.R.R., the B.R. & P.Ry., the P.R.R., the West Shore R.R., the M.C.R.R.,

the Grand Trunk Ry.—which also uses the L.V.R.R. Station—the D.L. & W.R.R. and the South Buffalo R.R. (passenger service suspended at present).

The Erie Station is the terminal of the Erie Railroad, Wabash Railroad and the New York Central and St. Louis Railroad.

The Lehigh Valley Station accommodates the Lehigh Valley Railroad and the Grand Trunk Railway.

North of Buffalo, at North Tonawanda, is a secondary railroad center where the three Niagara Falls branches of the N.Y. C. & H.R.R.R., the Erie R.R., and the L.V.R.R., which leave their trunk lines in different parts of the district, meet and join the Lockport and the B. & T. Branches of the New York Central.

An area measuring about 5½ miles by 3 miles in the center of Buffalo is free from railroads and is encircled by the New York Central Belt Line, connecting all railroads. South of this for about 1½ miles to Buffalo Creek is a network of yards which reaches from the water-front eastward to Lancaster; nearly all the large yards and many of the rail and water connections are here, with extensions along the river and harbor.

Terminal Railroads.

The Terminal Railroad of Buffalo, a N.Y.C. line, connects the eastern group of Lancaster with the southern group at Blasdell.

The Buffalo Creek Railroad is a switching road operating 31 miles of track along Buffalo Creek and giving access to an important part of the harbor, which extends 2½ miles up that waterway.

The Connecting Terminal Railroad is a Pennsylvania line to the water-front which has terminal warehouses.

The South Buffalo Railroad operates 62 miles of track south of Buffalo Creek for freight service only at present.

Rail and Water Connections.

Grain Elevators. Buffalo has 20 of these, total capacity 19,300,000 bushels. The transfer capacity from vessels to cars is probably 5,000,000 bushels per 24 hours.

Coal Trestles and Docks. Those of the P.R.R., D.L. & W. R.R., L.V.R.R., B.R. & P.Ry., Erie R.R., Philadelphia and Read-

ing Ry., and Williams have a capacity in pockets of 39,500 tons and can ship 25,000 tons per day.

Iron Ore Docks—Inner Harbor Terminals. The Lehigh Valley, N.Y.L.E. & W. and Buffalo ore docks receive about 3,000,000 tons annually.

Outer Harbor Terminals. The Pennsylvania Railroad and Buffalo and Susquehanna docks on their joint canal, with the Lackawanna Steel Co.'s canal and docks, handle and store about 3,000,000 tons of ore per year.

Lumber. The inner docks on the City Ship Canal and Ohio Basin (Barge Canal System) handle about 250,000 tons of lumber per year. There are other lumber docks on the Erie Basin.

Package Freight. Terminal warehouses are maintained by eleven railroads and steamship companies.

CLEVELAND RAILROAD SITUATION.

Cleveland is on a high plateau above Lake Erie and is divided into almost equal parts by the Cuyahoga River. The river occupies a valley of moderate width, which it crosses four times; it is navigable to the city limits.

The Lake Shore and Michigan Southern Ry. (N.Y.C.) and the New York, Chicago and St. Louis R.R. (Nickel Plate) pass through the city. The Baltimore and Ohio Railroad, the Erie Railroad, the Cleveland, Cincinnati, Chicago and St. Louis Ry. (Big Four), the Wheeling and Lake Erie Railroad, and the Pennsylvania system have lines terminating there. The roads enter radially from all directions on the land side. Four of the seven lines have separate passenger terminals—the L. S. & M. S. Ry., the P.R.R. and the C.C.C. & St.L.Ry. using the Union Station on the lake front. Most of the freight houses are in the valley and near the mouth of the river, but some are located near the lake front to the eastward.

The principal belt railroad is the Cleveland Short Line, which connects all railroads and has large freight yards. It is mostly used for through freight. The Newburgh and South Shore Ry. operates 45 miles of track and connects with four trunk lines and the belt railroad. It has a small passenger business, transfers freight between lines and handles much material for steel and wire manufacture.

The Cuyahoga Valley Ry. and the River Terminal Ry. are small lines connected with ore docks.

The "Silver Plate" connects the L.S. & M.S.Ry. and the P.R.R. with industries near the lake.

The Lake Erie Terminal Railroad, the Lake Erie and Pittsburgh Railroad and the Euclid R.R. are small outlying lines.

Rail and Water Connections.

There are many water-front terminals with railroad connections. Of these the P. R. R. owns thirteen, including a very large ore dock. It operates three and leases the others to private industries, etc. The B. & O.R.R. owns seven—five of which are leased to others and two are operated by itself. The Erie R.R. owns five, of which it operates three and leases two to private concerns. The W. & L.E.R.R. owns one, leased. The C.C.C. & St.L.Ry. owns four, all leased to private concerns. Steamship companies operate two of which one is leased from the C.C.C. & St.L.Ry. and the other is owned. The City of Cleveland owns two, both leased. There are also seventeen privately owned and operated water-front terminals with railroad connections.

Improvements Under Way. The city has filled 53 acres on the lake-front to be used for a Union Station and yards. Work is progressing on the straightening of the river to make room for freight yards. The City Council has voted on a fill for the lake-front for piers and yards, a tunnel to connect this with the railroads, and the vacation of streets for a large, high-level yard near the middle of the city.

ST. LOUIS RAILROAD SITUATION.

The trunk lines entering St. Louis are 20 in number. All use the Union Passenger Station, those from the west connecting with the Terminal Association tracks a short distance west of the station and those from the east using the Eads Bridge and the tunnel, both belonging to the Association.

The railroads which have lines on both sides of the river are:

Chicago, Burlington & Quincy R.R.
St. Louis, Iron Mountain & Southern Ry.
Wabash R.R.

The railroads having lines terminating at East St. Louis are:

Baltimore & Ohio, Southwestern R.R.
Chicago and Alton R.R.
Chicago & Eastern Illinois R.R. (with C.C.C. & St.L.).
Chicago, Peoria & St. Louis R.R.
Cleveland, Cincinnati, Chicago & St. Louis Ry.
Illinois Central R.R.
Louisville & Nashville R.R.
Louisville, Henderson and St. Louis Ry. (with L. & N. R.R.).
Mobile and Ohio R.R.
Southern Ry.
St. Louis, Southwestern Ry. (with Iron Mountain).
Toledo, St. Louis & Western R.R.
Vandalia R.R. (Pennsylvania system).

The lines from the west:

Chicago, Rock Island & Pacific Ry.
St. Louis & San Francisco R.R. (Frisco).
Missouri, Kansas & Texas Ry. (with C.B. & Q.R.R.).
Missouri Pacific Ry.

The Terminal Railroad Association of St. Louis and its associated lines have an extensive system of transfer railways for freight and passenger service. The Terminal Railroad Association operates the Union Station, Eads Bridge, St. Louis and East St. Louis Terminals. The associated companies are the St. Louis Merchants' Bridge Terminal Ry. Co., operating the Merchants' Bridge and terminals at St. Louis, Madison and Granite City; the Wiggins Ferry Co., operating the St. Louis Transfer Ry. and East St. Louis Connecting Ry. with car ferries and wagon ferries, and the Interstate Car Transfer Co. operating car ferries for carload freight.

Smaller lines about the city are:

The Manufacturers Ry. Co., with 21 miles of track near the water-front in the southern part of the city, connecting with the Iron Mountain and Belt Railroads and performing a transfer service.

The Municipal Railroad is owned by the City and operated by the Waterworks Department. It extends about 7½ miles parallel to the river in the northern portion of the city. Though now little used, it is considered of great importance as part of a future municipal transfer railroad made possible by expiring franchises.

On the East St. Louis side, the St. Louis & O'Fallon Ry. has 8.7 miles of line, and connects with the belt and two trunk lines.

The St. Louis, Troy and Eastern is a freight line with 26 miles of track, making connections at Edwardsville, Formosa Junction and East St. Louis with four lines and the belt line.

The Illinois Terminal Railroad (outside the limits of the map) has a line 21 miles long acting as a belt from Alton to Formosa Junction, crossing and connecting with 13 railroads.

The Missouri and Illinois Bridge and Belt Railroad has a bridge over the Mississippi and 3 miles of track at Alton, 23 miles above St. Louis.

Freight Houses and Freight Yards.

The roads terminating in East St. Louis have a group of freight houses and stub-track yards along the river front. Across the ends of these runs the transfer line of the Wiggins Ferry Co.; the Southern Ry. has larger yards parallel with the river. Farther back lie the National Stock Yards and the large railroad yards.

On the St. Louis side the freight houses are near the river north of the bridge. The Burlington has a great yard farther north. There is also a group of freight houses around the terminal tracks leading to the Union Station. The Mo. Pacific and Frisco lines have yards in this vicinity.

Rail and Water Connections.

There are fewer of these than in former times. Grain elevators on the St. Louis water-front and floating elevators are now no longer operated. The same is true of elevated conveyors and inclined tramways for transfer. Tipples for transferring coal to barges are used; they are of the car-on-end dumping type.

NEW ORLEANS RAILROAD SITUATION.

The eleven railroads terminating at New Orleans are:

East of the Mississippi River:

- Illinois Central R. R. & Yazoo and Mississippi Valley R. R.
- Louisiana Railway & Navigation Co.
- Louisiana Southern Ry. (Frisco Lines)
- Louisville & Nashville R. R.
- New Orleans & Northeastern R. R. (Queen & Crescent)
- New Orleans Great Northern R. R. (with Queen & Crescent)
- New Orleans, Texas & Mexico R. R. (Frisco Lines)

West of the Mississippi River:

- Morgan's Louisiana & Texas R. R. (Southern Pacific connection)
- New Orleans, Southern & Grand Isle Ry.
- Texas & Pacific R. R.

Of these the New Orleans & Northeastern Railroad, New Orleans, Texas & Mexico R. R., New Orleans Great Northern R. R. and Louisiana Ry. & Navigation Co. use the passenger terminals of the New Orleans Terminal Co.

The Illinois Central, Morgan's Louisiana & Texas R. R., the Texas & Pacific R. R. and the Yazoo & Mississippi Valley R. R. use one terminal. The Louisville and Nashville has its own station, as have also the small lines, the Louisiana Southern and the New Orleans Southern and Grand Isle.

Transfer Railroads.

The New Orleans Terminal Railroad operates 26 miles of main track and 37 miles of side tracks and yards, a passenger terminal, a water-front freight terminal and a grain elevator. It is not connected with ferry lines nor with the Public Belt Railroad.

The Illinois Central R. R. has a belt line along a large portion of the water-front.

The public belt line connects the publicly owned wharves with the railroads. It extends along the whole river-front. The line is owned and operated by the municipality.

Rail and Water Connections.

These are very extensive and efficient. The State owns most of the water-front, nearly six miles of public wharves, with 3½ miles of sheds served by the Public Belt R. R. In addition there are the Port Chalmette Terminals of the New Orleans Terminal R. R., the Stuyvesant Docks and Southport terminals of the Illinois Central R. R. and the Westwego terminals of the Texas & Pacific R. R. across the river. All of these except Southport have grain elevators. At Gretna on the west river bank the Southern Pacific has large terminals with cargo conveying machinery. Private stevedores have machinery for unloading bananas, coffee, etc. There are three private coal-handling plants. There is no public lighterage system.

In the preparation of this paper acknowledgement is made of the valuable assistance rendered by E. J. Murphy, assistant in the office of the Board of Commerce and Navigation, State of New Jersey, in the preparation of maps and details; to Mr. Bion J. Arnold, Consulting Engineer, for details concerning the situation in Chicago; to Mr. Harry C. Gahn, for information concerning the situation in Cleveland; to Mr. James F. Coleman, Consulting Engineer, for information concerning the situation in New Orleans; to Mr. G. H. Kimball, Consulting Engineer, for information concerning the situation at Buffalo; to Mr. Charles C. Butts, Prin. Ass't Engineer, Department of Public Utilities, City of St. Louis, for information concerning the situation at that city; and Mr. A. J. County, Special Assistant to the President of the Pennsylvania Railroad Co., for information concerning the situation at New York.

Certain statistics and information in this paper are taken from House of Representatives Document—63rd Congress, 1st Session, Document No. 226, entitled "Water Terminal and Transfer Facilities".

REFERENCES.

New York Harbor Railroad Map.

Baltimore & Ohio R.R.

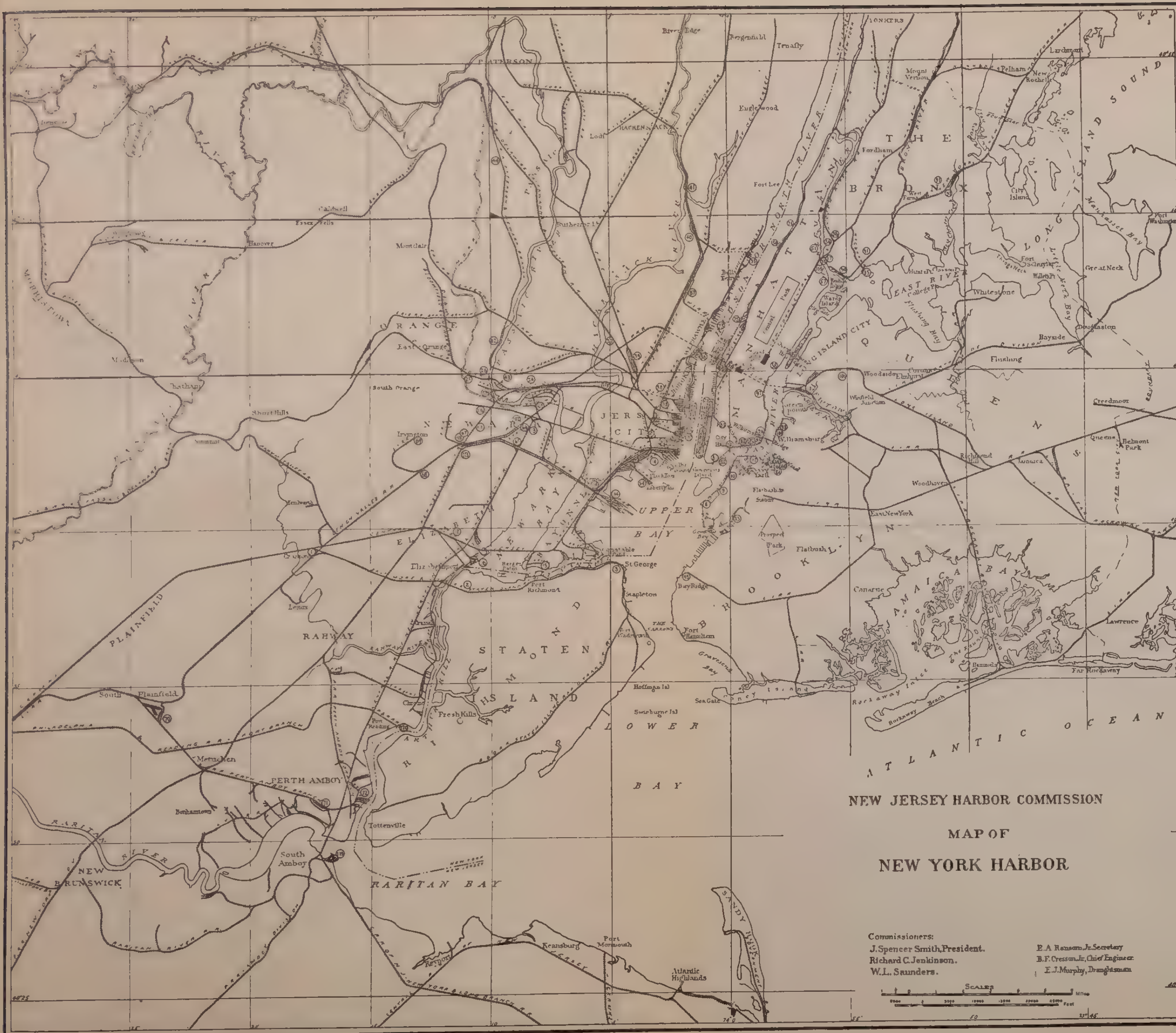
1 Cranford Yard—Receives and delivers C.R.R. of N.J. & L.V.R.R. freight.
2 Arlington Yard—Classification.
3 St. George Yard—Delivery for New York freight.
4 Wallabout Basin—Freight Pier.
5 Pier 7, North River, Freight Pier.
6 Piers 21 and 22, North River, Freight Piers.
7 Terminal Building, 27th St.
8 Freight Pier, King St.
9 Freight Pier, Baltic St.
10 Freight House, Joralemon St.
11 Freight Pier, Bridge St.

Central R.R. of New Jersey.

12 Elizabeth Yard—used also for Perth Amboy freight.
13 Holding Yard for Newark.
14 Passenger and Classification yard car float, transfer, lighterage to N. Y.
15 Bayonne Yard—Coal and Mdse.
16 Yard for coal shipments, Elizabethport Docks.
17 Bronx Yard—car float terminal
18 Freight Piers 10 and 11, North River.
19 Freight Pier 39, North River.
107 Hamburg Place, yard delivery.
108 Plank Road, yard delivery.
109 River St. freight station.
110 Alling St. yard.
111 South St. yard.
112 South Broad St. yard.

Delaware, Lackawanna & Western R.R.

20 Passenger Terminal—small freight yard.
21 Import and N. Y. Transfer Yard.
22 Export, Heavy Material, Holding Yard for N. Y.
23 Secaucus Yard—General freight west bound, gravity coal classification east bound.
24 Harrison Yard—Newark & Orange Freight.
25 Nesbitt St. Freight Yard—fed from Harrison Yard.
26 Broad St. Freight Yard—fed from Harrison Yard.
27 Freight Pier 13, North River.
28 Freight Pier 41, North River.
29 Freight Pier 68, North River.
30 Freight Pier 80, North River.
31 Freight Pier 26, East River.
32 Harlem Transfer.


NEW JERSEY HARBOR COMMISSION
MAP OF
NEW YORK HARBOR
Commissioners:
J. Spencer Smith, President.
Richard C. Jenkinson.
W.L. Saunders.
E.A. Ransom, Jr. Secretary
B.F. Cresson, Jr. Chief Engineer
E.J. Murphy, Draughtsman
SCALES
UPPER BAY
LOWER BAY
RARITAN BAY
ATLANTIC OCEAN
LONG ISLAND SOUND
JAMAICA BAY
STATEN ISLAND
NEWARK BAY
THE BRONX
QUEENS
BROOKLYN
MANHATTAN
JERSEY CITY
NEWARK
ELIZABETH
RAHWAY
PERTH AMBOY
NEW BRUNSWICK
PATERSON
HACKENSACK
ORANGE
PLAINFIELD
EAST RIVER
NORTH RIVER
St George
Stapleton
Tottenville
South Amboy
Metuchen
Bay Ridge
Fort Hamilton
Sea Gate
Coney Island
Rockaway Beach
Far Rockaway
Flushing
Whitestone
Great Neck
Jamaica
Woodhaven
East New York
Flatbush
Prospect Park
Canarsie
Keansburg
Port Monmouth
Atlantic Highlands
Sandy Hook
Englewood
Fort Lee
Tenafly
Bergenfield
New Rochelle
Pelham
Mount Vernon
Larchmont
Yonkers
Fordham
City Island
Bayside
Douglaston
Woodside
Corona
Williamsburg
Montclair
Caldwell
Hanover
Madison
Chatham
Short Hills
South Orange
East Orange
Irvington
Cranford
Lodi
Rutherford
Bonhamtown
Fresh Kills
Port Richmond
Elizabethport
Hoffman Isl
Swinburne Isl
Lawrence
Creedmoor
Belmont Park
Port Washington
Fort Schuyler
Willets Pt
College Pt
Long Island City
Central Park
Manhasset Bay
Gravesend Bay
Rockaway Inlet
Plate I.

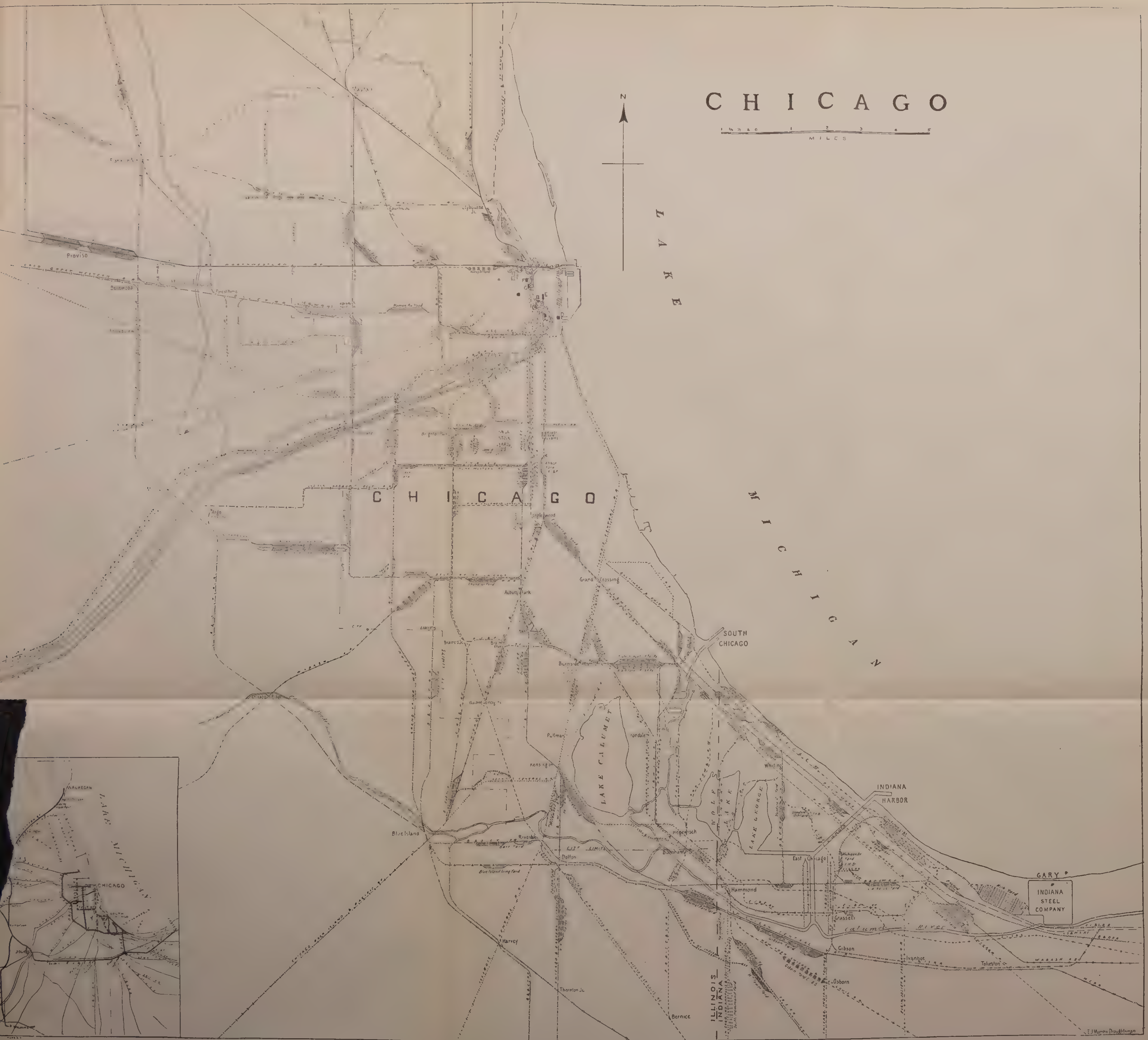

CHICAGO
N
MILES
LAKE
MICHIGAN
CHICAGO
Proviso
Englewood
Grand Crossing
Auburn Park
SOUTH
CHICAGO
Burnside
Pullman
Kensington
LAKE CALUMET
WOLF LAKE
LAKE GEORGE
INDIANA
HARBOR
Blue Island
Riverdale
Dolton
Hegewisch
Burnham
East Chicago
Hammond
GARY
INDIANA
STEEL
COMPANY
Grasselli
Gibson
Ivanhoe
Tolleston
Osborn
Harvey
Thornton Jc.
Bernice
ILLINOIS
INDIANA
CITY LIMITS
WABASH R.R.
MICHIGAN
LAKE MICHIGAN

Plate II.

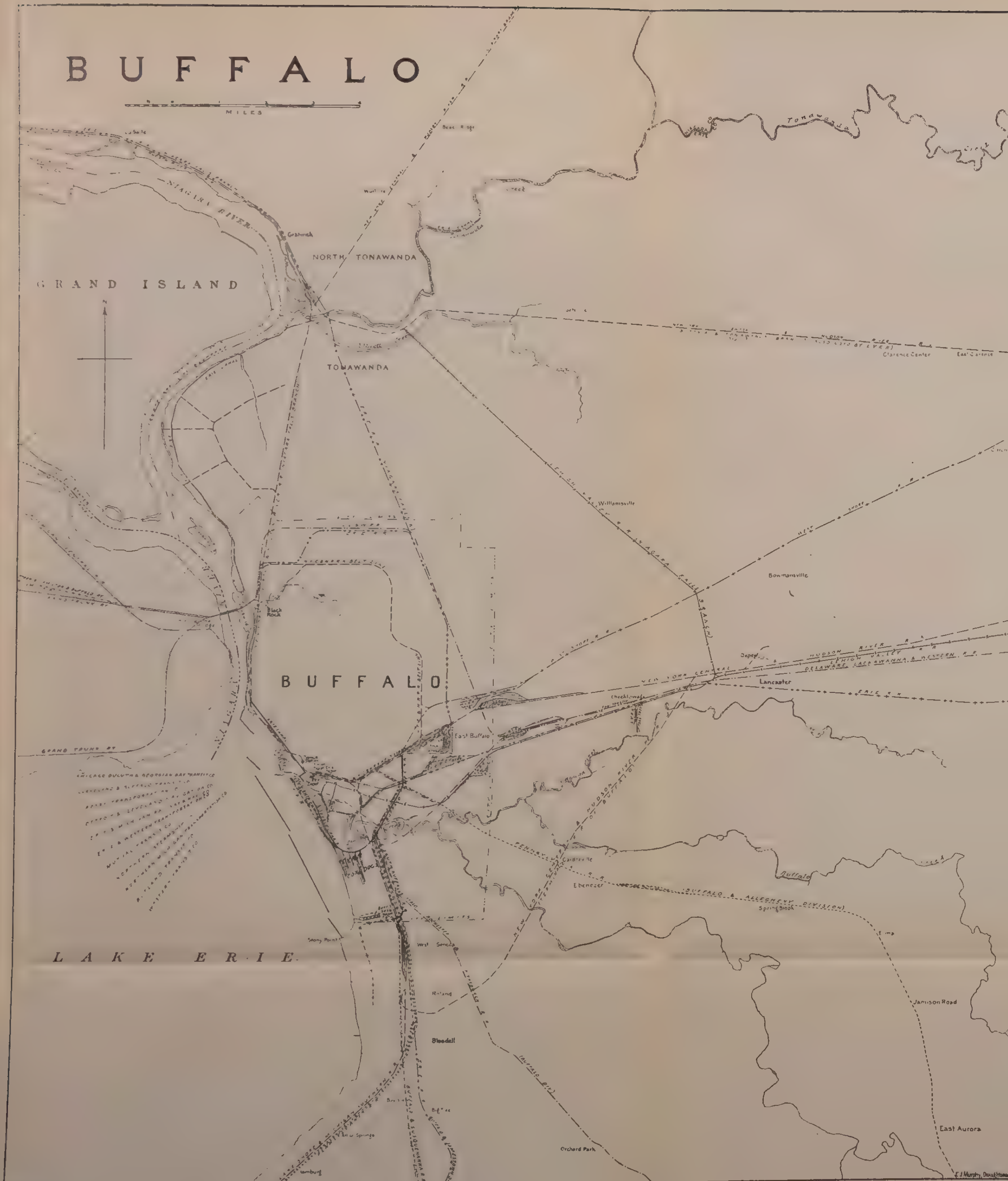

BUFFALO
MILES
GRAND ISLAND
NIAGARA RIVER
NORTH TONAWANDA
TONAWANDA
Williamsville
Bowmansville
BUFFALO
Black Rock
Lancaster
Clarence Center
East Clarence
NEW YORK CENTRAL
HUDSON RIVER
LEHIGH VALLEY
DELAWARE LACKAWANNA & WESTERN R.R.
ERIE R.R.
East Buffalo
Cheektowaga
GRAND TRUNK RY
Gardenville
Ebenezer
Spring Brook
BUFFALO & ALLEGHENY DIVISION
Buffalo
West Seneca
Stony Point
LAKE ERIE
Roland
Blasdell
Jamison Road
East Aurora
Orchard Park
Hamburg
E.J. Murphy, Draughtsman

Plate III.


CLEVELAND
LAKE ERIE
N
CLEVELAND
LAKE SHORE & MICHIGAN SOUTHERN RY
NEW YORK CHICAGO & ST LOUIS R R
CLEVELAND SHORT LINE RY
PENNSYLVANIA
ERIE R R
CLEVELAND SHORT LINE RY
BALTIMORE & OHIO
LAKE ERIE TERMINAL R R
LAKE ERIE & PITTSBURGH RY
PENNSYLVANIA
LAKE ERIE R R

Plate IV.

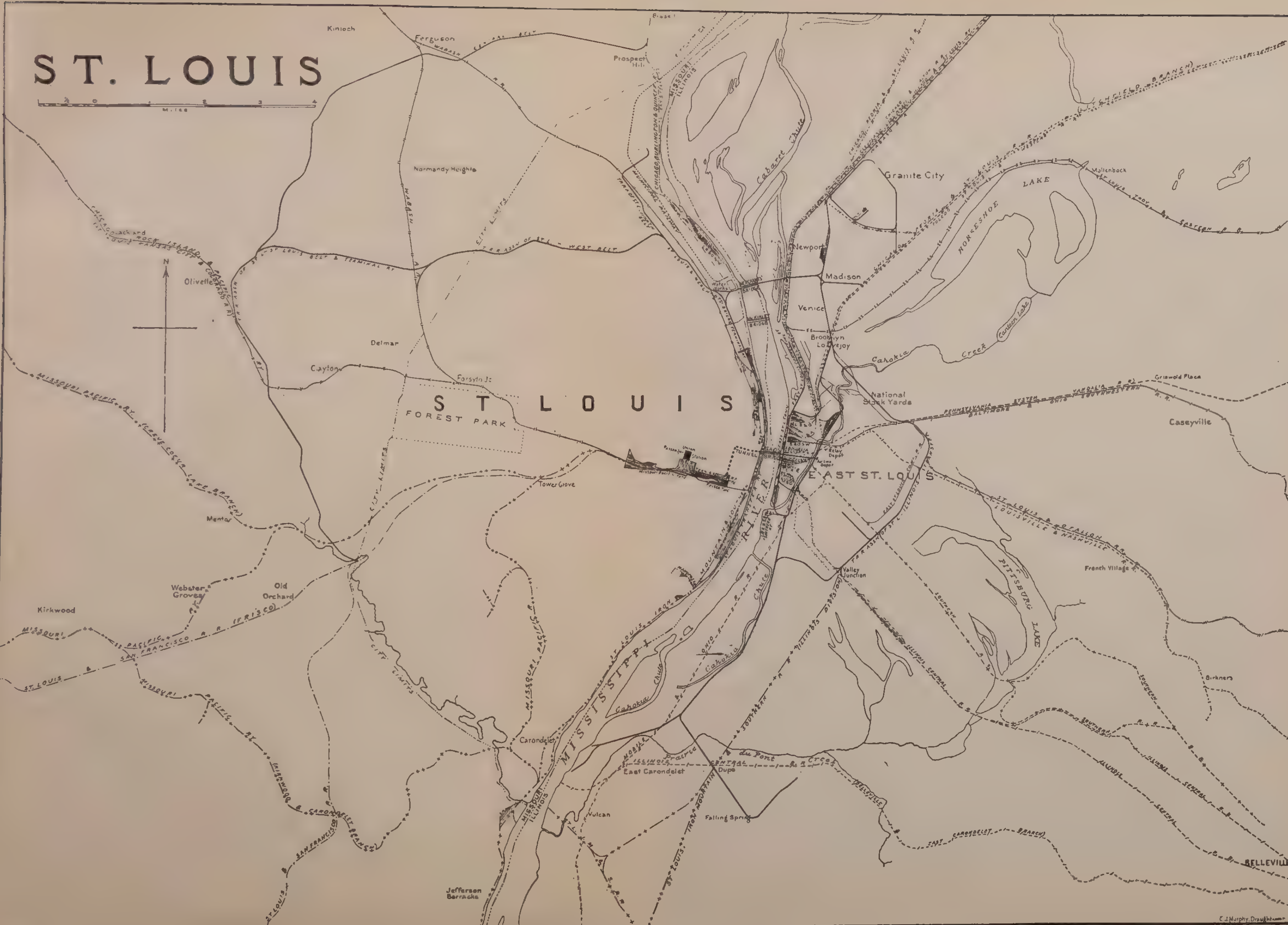

ST. LOUIS
Miles
Kinloch
Ferguson
Prospect Hill
Normandy Heights
Granite City
Mollenbock
Horseshoe Lake
Newport
Madison
Venice
Brooklyn
Lovejoy
Cahokia Creek
Canteen Lake
Cabaret Chute
National Stock Yards
Griswold Place
Caseyville
Olivette
Delmar
Clayton
Forsyth Jc.
ST. LOUIS
FOREST PARK
Union Station
Tower Grove
EAST ST. LOUIS
Mississippi River
Mentor
Valley Junction
French Village
Pittsburg Lake
Webster Groves
Old Orchard
Kirkwood
Cahokia Chute
Carondelet
East Carondelet
Prairie du Pont Creek
Dupo
Vulcan
Falling Spring
Birkners
BELLEVILLE
Jefferson Barracks
Missouri Pacific Ry.
St. Louis & San Francisco R.R. (Frisco)
Chicago, Rock Island & Pacific
Wabash R.R.
Terminal R.R. Ass'n of St. Louis
Pennsylvania System
Baltimore & Ohio Southwestern R.R.
Vandalia R.R.
St. Louis & O'Fallon R.R.
Louisville & Nashville R.R.
Illinois Central R.R.
Southern R.R.
Mobile & Ohio R.R.
St. Louis, Iron Mountain & Southern
City Limits
C. J. Murphy, Draughtsman

Plate V.


LAKE PONTCHARTRAIN
NEW ORLEANS
MILES
West End
Spanish Fort
Milneburg
PARISH OF JEFFERSON
PARISH OF ORLEANS
PUBLIC BELT R.R.
LOUISVILLE & NASHVILLE R.R.
ILLINOIS CENTRAL R.R.
YAZOO & MISSISSIPPI VALLEY R.R.
SHREWSBURY
LOUISIANA RY & NAVIGATION CO.
Southport
NEW ORLEANS
NEW ORLEANS TERMINAL CO.
Government Yard
MISSISSIPPI
RIVER
PUBLIC WHARVES
Westwego
AVONDALE
ALGIERS
Algiers Yard
GOULDSBORO
GRETNA
AMESVILLE
TEXAS & PACIFIC R.R.
MORGAN'S LOUISIANA & TEXAS R.R. (SOUTHERN PACIFIC)
I.C. BELT LINE
I.C.R.R. Grain Elevators
PARISH OF ORLEANS
PARISH OF ST. BERNARD
LOUISIANA SOUTHERN R.R.
N
E. J. Murphy, Draughtsman

Plate VI.

33 Brooklyn Freight House.
34 Wallabout Freight Pier.

Erie R. R.

35 N.Y.S. & W. Terminal—coal delivery.
36 Weehawken Yard, holding and lighterage for New York.
37 Passenger Yard—transfer, lighterage, grain elevator.
38 Coach Yard.
39 Main Yard—classification—engine terminal.
40 Coalburg—east bound—coal empties from N.Y.S. & W. Terminal.
41 Little Ferry—General freight yard N.Y.S. & W. Interchange with W.S.R.R.
42 General freight yard for Newark.
43 Harrison—stock yards.
44 Athenia—cattle quarantine.
45 Freight Pier 21, North River.
46 Freight Pier 39, North River.
47 Freight yard, W. 28th St., Manhattan.
48 Freight Pier 80, North River.
49 Freight Pier 89, North River.
50 Freight Pier 121, North River.
51 Harlem Terminal, Park Av. and 135th St., Manhattan.
52 Freight Pier 7, East River.

Lehigh Valley R.R.

53 Jersey City Terminal—transfer and lighterage to N. Y.
54 National Stores—warehouses, grain elevator.
55 Public Delivery Yard, 27th St., Manhattan.
56 Public Delivery Yard and Freight Pier, 149th St.
57 Public Delivery Yard, E. 124th St., Manhattan.
58 Slaughter house and freight station, E. 43rd St.
59 Freight Pier 44, East River.
60 Freight Pier 5, Wallabout Basin.
61 Freight Pier 3, North River.
62 Freight Pier 34, North River.
63 Grand St. freight yard, Jersey City.
64 Greenville freight yard, Jersey City.
65 Oak Island Yards and transfer.
66 Hamburg Place freight station, Newark.
67 Poinier St. freight yard, Newark.
68 W. Elizabeth freight yard.
69 Irvington freight yard.
70 South Plainfield freight yard.
71 Perth Amboy freight yard.
72 Perth Amboy freight and coal piers.

New York Central & Hudson River R.R.

73 West Shore Yard—passenger terminal classification, lighterage and transfer to New York, grain elevator.

74 144th St. Docks.
75 60th St. Yard classification, transfer bridges, lighterage, stock yards, grain elevator.
76 30th St. Yard—Piers, teamtracks, milk yard, market facilities, freight houses.
77 42nd St. Ferry, 43rd St. Freight Pier.
78 Freight Pier 31, North River.
79 Freight Pier 23, North River.
80 Freight Pier 16 and 17, North River.
81 Freight Pier 4, East River.
82 Freight Pier 34, East River.
83 St. Johns Park, freight house, track delivery.
84 Wallabout Basin, freight house.
85 Port Morris Yard, piers, transfer to N.Y.N.H. & H., power house.
86 Mott Haven Yard—passenger cars—small freight yard.
87 New Durham Yard—classification—principal holding yard.
88 Hoboken freight house.
89 Newark Av. freight yard, Jersey City.

New York, New Haven & Hartford R.R.

90 Harlem River Yard—lighterage, transfer bridges, local freight house, L.C.L. & bulk, produce house, with stalls, transfer between harbor lines.
91 Oak Point Yard—car float, transfer eastbound and westbound—20% of eastbound classification here.
92 West Chester Yard—Classification of 80% of eastbound freight—L.C.L. transfer platform.
93 Van Nest Yard—storage and empties.
94 Freight Pier 39, East River.
95 Freight Pier 45, East River.
96 Freight Pier 50, East River.
97 Freight Pier 70, East River.
98 Freight Pier Foot of N. First St., Greenpoint.

Pennsylvania R.R.

99 Hudson St. Branch, local industries.
100 Freight Piers 1, 3, 4 and 5, North River.
101 Freight Piers 27, 28 and 29, North River.
102 Freight Piers 77 and 78, North River.
103 Freight Piers N. 4th and N. 5th Sts., Brooklyn.
104 Freight Piers 2, Wallabout Basin.
105 Freight Piers at 125th St. and Harlem River, Manhattan, lighterage.
106 Sunnyside Passenger Yard.
113 Waverly Yard—Jersey City and New York freight classification, transfer, L.C.L. delivery.
114 Greenville Yard—through yard, classification of New England freight.
115 Meadows Yard, classification for Harsimus Cove yard.

116 Harsimus Cove Yard—transfer bridges, lighterage, local freight, Jersey City, stock yards.
117 Jersey City Yard—Passenger terminal, transfer bridges, team tracks.
118 Bay Ridge Terminal.
119 South Amboy coal piers.

Philadelphia & Reading R.R.

120 Port Reading Terminal.

Chicago Railroad Map.

Location of Down-Town Freight Houses.

1 C.G.W.R.R., Inbound and Outbound.
2 B. & O.R.R., Inbound and Outbound.
3 C.R.I. & P.Ry., Inbound and Outbound.
4 L.S. & M.S.Ry., Inbound and Outbound.
5 N.Y.C. & St.L.R.R., Inbound and Outbound.
6 Erie R.R., Inbound and Outbound.
7 G.T.W.Ry., Inbound.
8 Wabash R.R., Outbound.
9 C.I. & L.Ry., Inbound and Outbound.
10 C. & E.I.R.R., Inbound and Outbound.
11 Wabash R.R., Inbound.
12 G.T.W.Ry., Inbound and Outbound.
13 A.T. & S.F.Ry., Outbound.
14 A.T. & S.F.Ry., Inbound.
15 C.B. & Q.R.R., Inbound and Outbound.
16 C.B. & Q.R.R., Inbound and Outbound.
17 C. & N.W.R., Outbound.
18 C.M. & St.P.R.R., Outbound.
19 M.St.P. & S.S.M.Ry., Inbound and Outbound.
20 B. & O.R.R., Inbound and Outbound.
21 C. & A.R.R., Inbound and Outbound.
22 C.B. & Q.R.R., Inbound and Outbound.
23 C.M. & St.P.R.R., Inbound.
24 C.M. & St.P.R.R., Inbound.
25 C.M. & St.P.R.R., Outbound.
26 C.M. & St.P.R.R., Outbound.
27 C. & N.W.Ry., Inbound.
28 C. & N.W.Ry., Inbound.
29 C. & N.W.Ry., Outbound.
30 C. & N.W.Ry., Outbound.
31 I.C.R.R., Inbound and Outbound.
32 M.C.R.R., Inbound and Outbound.
33 P.M.R.R., Inbound and Outbound.
34 P.C.C. & St.L.Ry., Inbound.
35 P.C.C. & St.L.Ry., Inbound.

36 P.C.C. & St.L.Ry., Outbound.
37 P.F.W. & C.Ry., Inbound.
38 P.F.W. & C.Ry., Inbound.
39 P.F.W. & C.Ry., Outbound.
40 P.F.W. & C.Ry., Outbound.

Location of Passenger Terminals.

A Dearborn Station, terminus of
Atchison, Topeka & Santa Fe Ry.
Chesapeake & Ohio Ry. of Indiana.
Chicago & Eastern Illinois R.R.
Chicago & Western Indiana R.R.
Chicago, Indianapolis & Louisville R.R.
Erie R.R.
Grand Trunk Western Ry.
Wabash R.R.

B Grand Central Station, terminus of
Baltimore & Ohio Southwestern R.R.
Chicago Great Western R.R.
Minneapolis, St. Paul & Sault Ste. Marie Ry.
Pere Marquette R.R.

C Union Passenger Station, terminus of
Chicago & Alton R.R.
Chicago, Burlington & Quincy R.R.
Chicago, Milwaukee & St. Paul R.R.
Pennsylvania System. { Pittsburgh, Fort Wayne & Chicago Ry.
Pittsburgh, Cincinnati, Chicago & St. Louis R.R.

D Central Station, terminus of
Illinois Central R.R.
Michigan Central R.R.
Cleveland, Cincinnati, Chicago & St. Louis Ry.

E La Salle St. Station, terminus of
Lake Shore and Michigan Southern Ry. (N.Y.C.)
New York, Chicago & St. Louis R.R.
Chicago, Rock Island & Pacific Ry.

F Chicago & Northwestern Station, terminus of
Chicago & Northwestern Ry.

Cleveland Railroad Map.

Baltimore & Ohio R.R.

1 Columbus Road Freight Station, Inbound and Outbound
2 Lake Dock.
3 Lake Warehouse.
4 Seneca St. Freight House, Outbound.
5 South Brooklyn Passenger and Freight Station, Inbound and Outbound.

6 Willow Passenger and Freight station, Outbound and Inbound.
7 Seneca St. Dock.
8 Brooklyn Team Tracks.
9 Factory St. Team Tracks.
10 Merwin St. Team Tracks.
11 Newburgh Freight Station.
12 Brooklyn Passenger and Freight Station, Inbound and Outbound.
13 Passenger Station, Cleveland.
13A Parma Station.

Cleveland, Cincinnati, Chicago & St. Louis Ry.

14 Central Flats Freight Station, Outbound.
15 Front St. Freight Station, Inbound.
16 Oil Freight Station, Outbound.
17 Linndale Passenger and Freight Station, with team track.
18 Spring St. Team Track.
19 Central Flats Team Track.
20 Gordon Avenue Team Tracks.
21 Scott Team Tracks, Inbound.
22 Swiss St. Team Tracks
23 Wall Team Tracks.
24 West 41st St. Team Tracks.
25 Union Passenger Station.

Cleveland Short Line.

26 Schaaf Road Team Tracks.

Erie R.R.

27 Passenger Station (with C.C.C. & St.L.Ry.).
28 Coal Unloader.
29 Dock, Elm St. Freight Station, Lake Transfer Station.
30 Newburgh Freight and Passenger Station.
31 Scranton Road Freight Station, Lumber Dock.
32 Willson Avenue Passenger Station and Freight Station.
33 Ore Docks.
34 Broadway Team Tracks.
35 Columbus Road Team Tracks.
36 Forest Street Team Tracks.
37 River Bed Team Tracks.

Lake Shore and Michigan Southern Ry.

25 Union Passenger Station.
38 Central Way Freight Station, Outbound.
39 Detroit Av. Freight Station, Inbound and Outbound.
40 E. 105th St. Passenger Station and Freight Station, Inbound and Outbound.
41 Front St. Freight Station, Inbound.
42 Pier Freight Station, Inbound.
43 Pier Freight Station, Outbound.

44 Wason St. Freight Station, Outbound.
45 Wason St. Freight Station, Inbound.
46 West Park Passenger Station and Freight Station.
47 Ice House.
48 Collingwood Passenger and Freight Station.
49 Davenport Av. Team Tracks.
50 East 67th St. Team Tracks.
51 Willow St. Team Tracks.

Newburgh & South Shore Ry.

52 Broadway Passenger Station and Team Tracks.
53 Cleveland Passenger Station.
54 Cuyahoga Av. Passenger Station.
55 East 71st St. Passenger Station and Team Tracks.
56 Campbell Road Team Tracks.
57 East 91st St. Team Tracks.
58 Harvard Av. Team Tracks.
59 Independence Road Team Tracks.
60 Seneca St. Team Tracks.

New York, Chicago & St. Louis Ry.

61 East 9th St. Freight Station, Inbound and Outbound.
62 East 79th St. Station, Inbound and Outbound.
63 West 25th St. Freight Station, Inbound and Outbound.
64 Broadway Passenger Station.
65 Euclid Av. Passenger Station.
66 W. 25th St. Passenger Station.
67 Crosby Av. Team Tracks.
68 East 89th St. Team Tracks.
69 Ivanhoe Road Team Tracks.
70 Mayfield Team Tracks.
71 Pear Av. Team Tracks.
72 West 42nd St. Team Tracks.
73 West 110th St. Team Tracks.

Pennsylvania R.R.

25 Union Passenger Station.
74 Cleveland Freight Station, Inbound and Outbound.
75 Pier and Lake Freight Station, Inbound and Outbound.
76 Pier No. 1, Freight Station, Inbound and Outbound.
77 Piers No. 2 and 3, Freight Station, Inbound and Outbound.
77 Euclid Av. Freight Station, Inbound and Outbound.
78 Newburgh Freight Station, Inbound and Outbound.
79 Wason St. Freight Station, Inbound and Outbound.
80 Woodland Av. Freight Station, Inbound and Outbound.
81 Euclid Av. Passenger Station.
82 Newburgh Passenger Station.
83 Woodland Av. Passenger Station.
84 Keiper St. Team Track.

Wheeling and Lake Erie R.R.

85 Coal Dock.
86 Commercial Road Freight Station, Inbound.
87 Commercial Road Freight Station, Outbound.
88 East 93rd St. Passenger and Freight Station, Inbound and Outbound.
89 Broadway Passenger Station.
90 Miles Av. Passenger Station.
91 Ontario St. Passenger Station.
92 Ore Dock.
93 Broadway Team Tracks.
94 Brooklyn Team Tracks.
95 Jones Road Team Track.
96 Ridge Road Team Track.
97 West 3rd St. Team Track.

Steamship Lines.

98 Anchor Line.
Canadian Lake Line.
99 Detroit and Cleveland Navigation Co.
100 Inland Line, Ltd.
100 Merchants' Montreal Line.
98 Mutual Transit Co.
98 Northern Steamship Co.
100 Star Cole Lines.

DISCUSSION

Mr. Smith.

Mr. J. Spencer Smith* (by letter) expressed the belief that Mr. Cresson has pointed out what is the crux in the railroad situation of the United States when he refers to the regulation of rates between points by the Interstate Commerce Commission and the freedom given to railroads in competing with one another at terminal points.

The writer takes it for granted that the reason the Interstate Commerce Commission has been given the power to regulate rates is so that the best interests of the country may be served, as well as that the stockholders of the railroads may receive protection from ruinous competition.

He believes it to be very generally accepted today that railroads are quasi-public institutions and that their primary interest is to serve the people as a whole. If this is the case, then it seems that it would be in line with the Interstate Commerce Commission's duties if they were to compel the railroads serving large centers to form terminal operating companies which would handle the business of the roads terminating at these centers. A striking example of how the Union Operating Company promotes the commercial welfare of a community is shown in Montreal. Not many years ago the railroads terminating in Montreal did their own switching and each one handled its own business; whereas today, so far as the business of the port of Montreal is concerned, the railroads turn

* President, Board of Commerce and Navigation, State of New Jersey.

Mr. Smith. over their business to the Harbor Commission and the Harbor Commission in turn operates the terminal railroad. This arrangement has proved to be most satisfactory to the shippers as well as the railroad companies.

Mr. Tomkins. **Mr. Calvin Tomkins,*** Assoc. Am. Soc. C. E. (by letter), said that Mr. B. F. Cresson's interesting experience as port engineer alternately in the service of New York City and the State of New Jersey, situated as they are on both sides of the great international port of New York, peculiarly qualifies him to discuss the problem of railway terminals. Nowhere is this problem more complicated or urgent than at the principal port of the country.

Mr. Cresson has very clearly stated in his text and shown graphically by the maps which accompany it the universality of the principle that the railroads which converge at a city should be fused into one connected, administrative terminal unit, so that every factory and warehouse in any part of the city shall have ready access to all routes leading to and from it. If the city is also a port, the marine traffic should be articulated with the rail traffic at the water front through the instrumentality of a marginal railroad behind the docks, over which traffic should move with as little obstruction as does the water-borne traffic in front of the docks.

The cities have heretofore neglected their terminal responsibilities, and especially is this true of the ports. The railroads were originally obliged to create their own terminals, and incidentally terminal abuses crept in. The resulting unrelated, private and unsocial terminal systems are breaking down as a consequence of their inherent defects, and the problem which now arises is not so much that of physical organization—since the general principles involved are common to most cities, as Mr. Cresson has shown—but rather to determine how the railroads can let go and the public take hold without prejudice to the fundamental interests of either, or of the shippers and receivers of freight.

Mr. James J. Hill has truly said that the railroad system of the country is breaking down at its constricted outgrown city terminals. When the war stops and general business revives, the need for a change of policy involving the substitution of co-operation for competition will quickly become obvious.

Mr. Williams. **Mr. Riley Williams**† (by letter) said that there are no features of the many functions of the modern railroad so vitally essential to successful management as adequate and scientifically planned terminals combined with competent and efficient terminal supervision.

In the past the lack of provision for the expansion of existing terminals has resulted in a serious burden to the majority of our American railroads; and while the railroads of this country are laboring under difficulties at practically all important terminal points, the situation seems most accentuated and serious at points along the Atlantic seaboard.

* New York City, N. Y.

† Formerly Terminal and Lighterage Agent for the Delaware & Lackawanna Railroad Company at the Port of New York.

Mr. Williams.

At no other locality have conditions become so acute as at the port of New York. There terminal facilities have been provided looking to the requirements of each individual road only, and without any regard to some general and comprehensive plan of port and terminal development looking toward the growing necessities of the port considered as a whole.

There are nine trunk lines reaching the port of New York from the South and from the West passing in and out through the New Jersey gateway. The freight brought to and taken from the port of New York by these nine trunk lines aggregates more than 35,000,000 tons per annum. The major part of this vast tonnage breaks bulk on the Jersey side of the Hudson River, and, consequently, must be carried to ultimate destination for points in the harbor by means of water transportation.

This method of joint rail and water terminal distribution, which in no small measure is subject to weather conditions and to the limitations of floating equipment, is, naturally, more or less ''sluggish'' in movement, and highly expensive, necessitating, as it does, several handlings of the cargo itself, to say nothing of the numerous and complicated yard movements entailed in effecting deliveries from rail to water carriers, and vice versa.

In this confused terminal situation there are approximately seventy railroad stations scattered in and about New York, Brooklyn, Staten Island and New Jersey. Practically all of these stations are dependent on water transportation from and to rail terminals.

There are, approximately, seventy-five steamship lines with regular sailings, to which freight must be delivered subject to ''holding periods'' (ranging from 5 to 60 days, as per current rules) in yards and on piers on the New Jersey side of the Hudson River, thus unquestionably creating the most costly and confused aggregation of dissimilar units of terminal operation to be found any place on this continent; indeed, there is no other point where the railroads perform the amount of unremunerative service that they do at the port of New York. This latter, however, has not been entirely due to the prevailing physical conditions. In no small degree it has been the result of competition between the rail carriers, dating back many years; and the practices growing out of such competition have now become so firmly intrenched as to make it a difficult, if not an impossible, problem to introduce necessary adjustment features under the existing supervision of the Interstate Commerce Commission.

Another serious situation existing at the port of New York, unlike any other large center throughout the country, is the lack of belt-line railroad facilities where traffic can pass from one line to another, and in some instances traffic originating near the port in New Jersey or passing from one line to another is carried as far as 80 miles each way inland for interchange.

However, there are many very heavy traffic centers throughout the United States where the enormous growth of our cities, with their ever-widening limits, during the past half century has outstripped the develop-

Mr. Williams. ment of railroad terminal facilities, and property adjacent to the tracks has been in such great demand for commercial and industrial purposes, and has so increased in value, as to render its use for railroad terminal facilities impractical, even where physical conditions are satisfactory.

Terminal enlargements throughout the country, at best, are now extremely expensive, so that it is difficult to justify their cost for a terminal improvement, and the future development of terminal facilities must therefore be provided largely by cheaper operation, cheaper land and the development of modern facilities. At each of the large terminals there should be provided a system of warehouses where equipment can be quickly unloaded on arrival, instead of congesting yards and creating heavy terminal expense.

How can one justify the wisdom of running traffic from Chicago and from St. Louis at a speed which will effect an 80-hour delivery at the port of New York, and then have this same traffic stand in terminals from 10 to 60 days, congesting yards, to say nothing of the loss in time to equipment?

Our commercial development for the past 25 years has been phenomenal; it will continue and the situation thus created must be met by providing better and more scientific terminal facilities. During these 25 years, generally speaking, terminal facilities have only been added as they were actually required, by a hand-to-mouth method, while tracks, motive power and car equipment have been provided in anticipation of the coming needs. American railroads have been developed to a high standard of efficiency in every respect, excepting in their terminals, which, in many cases, have been sadly neglected, but at no other point has the situation become so serious as at the port of New York.

Paper No. 90

RECENT LOCOMOTIVE DEVELOPMENT.

By

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Within recent years there have been four distinct lines of advancement followed in steam locomotives, which may be grouped into size, type, details and adjuncts; and that we may better present the effect of the changes for each of these groups, they will be taken up separately and discussed in the order mentioned.

SIZE AND TYPES.

As the first two classifications are so intimately connected, it will be advisable to consider them at the same time. The important changes which have been brought about in these groups, have occurred mostly within the last ten or fifteen years. While increase in weight has been going on steadily for a long time, in fact, ever since the locomotive was first given to the use of man, yet the advances in this direction were gradual, and it is only recently that really enormous locomotives have been constructed, and that the increases in size and weight have so rapidly developed into the dimensions of the present day. What can be done in the future is still in doubt; but with the limits to which rolling stock is now confined, due to the heights of bridges and tunnels, and the side clearances of these and also of station platforms, rock cuts, signals, etc., it is hard to see how anything much further can be accomplished, except in the direction of length.

The reason for the great increase in size, which has recently come about, is not hard to find. The advent of large capacity freight cars has resulted in a train that could be more easily handled with a large tonnage than was possible

in the old cars of smaller capacity, as the operation of the brakes depends more upon the length of the train and the number of units than the individual braking capacity of each car. Instead of thirty tons capacity, which was originally the maximum equipment in use about ten years ago, we now have cars of fifty tons as a very large proportion of the make-up of ordinary freight trains, and even gondolas of one hundred tons capacity are being developed and tried.

In regard to passenger equipment, the introduction of the steel car has added very considerably to the weight which must be hauled; and besides, the increase in traffic due to the natural growth of the population, which has, for the United States, amounted to 20% in the last ten years, calls for large additions to side tracks, motive power and other provisions for increasing movement of persons and freight.

The fact that a large train can be handled as a rule much more cheaply per ton than a small train, calls for efforts in this direction, as under the present operating conditions, it is essential that every economy be observed in railroad work.

All this, of course, means that we must have heavier track and bridges; but when we are able to increase the length of the locomotive at the same time that we increase its weight, the strain is much less upon the track and bridges than if the increase of load were obtained by varying only the other dimensions. That this latter policy has been followed as far as possible, is shown by the fact that while a few years ago, 25 tons was thought to be a large weight on one pair of drivers, we now have 30 and 35 tons in the same cases per driving axle. This allowance per pound of rail per yard is much greater in America than in Europe.

The lengthening of the locomotive, however, brings about a new condition; in the first place, this means the lengthening of the boiler so as to require longer flues, combustion chambers, long fire boxes and long smoke boxes. The wheel base must naturally follow the lengthening of the boiler, and this calls for the addition of trailing trucks, where formerly a front truck and one set of driving wheels were used. Thus, we have the old American 4-4-0 type converted to the Atlantic, or 4-4-2, type; the old 10-wheel, or 4-6-0, type converted to the Pacific,

or 4-6-2, type and the Consolidation, or 2-8-0, type converted to the Mikado, or 2-8-2, type.

This lengthening of the boiler has an advantage, not for increasing the adhesion of the engine, and its ultimate tractive force, but for increasing the steaming capacity, whereby a greater tractive force can be maintained at a higher speed, and

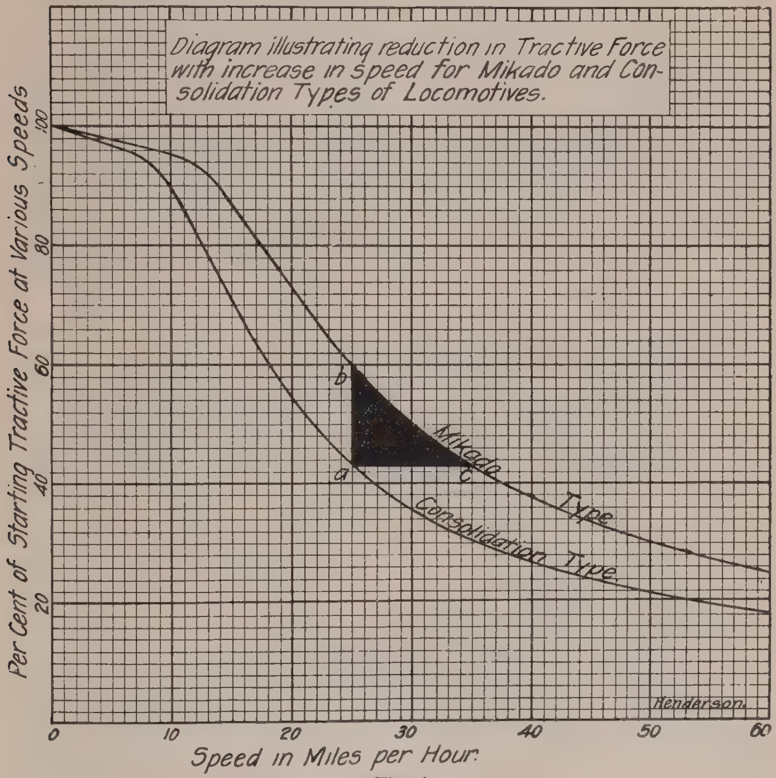


Fig. 1.

this is shown in Diagram No. 1, where the available tractive force at a given speed, or the available speed at a given tractive force, is considerably increased by the adoption of the rear truck and the large boiler, which it is possible to use with this extended wheel base.

In the diagram, consider a Consolidation locomotive which, at 25 miles per hour, can exert a tractive force of 43% of its

starting tractive force. Now, if we have a Mikado engine of the same adhesive weight, size of cylinders, etc., but with the correspondingly larger boiler, we can exert the same percentage of the total tractive force at 35 miles instead of 25 miles per hour, or we can exert 60% of the rated tractive force at 25 miles per hour instead of 43%. These are shown at the points a, c and b, respectively, on the diagram, and the black area covers the portion of the diagram where an increase in either the tractive force or the speed or both can be obtained, without any corresponding decreases either in the speed or tractive force.

As a forcible example of how these types with trailing trucks have come into general use, let us consider some of the features of locomotives ordered in 1902 and then in 1913. In the first year mentioned, the heaviest Atlantic type had a total weight of 178,000 lbs. (81 tonnes), and the heaviest Consolidation, 270,000 lbs. (122 tonnes). In this year, only 37 Pacific type locomotives, the heaviest being 230,000 lbs. (104 tonnes), and only 15 Mikados of 285,000 lbs. (130 tonnes) were ordered.

Eleven years later, we find that while the weight of the heaviest Consolidation locomotive remained the same, yet the heaviest Atlantic type had increased to 240,000 lbs. (109 tonnes), and that there were actually 431 Pacific type locomotives ordered, the heaviest weighing 290,000 lbs. (132 tonnes), and 804 Mikados, the heaviest weighing 344,000 lbs. (156 tonnes). This increase in weight and in the number of engines of the new types is truly remarkable, and shows what the desire for a heavier train load and increased economy will effect. In addition, there have been quite a number of 2-10-2 locomotives built in recent years, with weight greater than the Mikado locomotives above mentioned.

Among the interesting engines with a single pair of cylinders and a single set of driving mechanism recently constructed, may be noted the American, or 4-4-0 type, of the Philadelphia & Reading Railway, shown by Figure No. 2 and which has 120,000 lbs. (55 tonnes) on driving wheels with a total weight of engine and tender of about 157 tons (143 tonnes). The cylinders are 21″ x 24″ (533 x 609 mm.) and the generating heating surface 1517 sq. ft. (141 sq. metres), with 86 sq. ft.

Fig. 2. American Type (4-4-0) Locomotive; Phila. & Reading Ry.
Fig. 3. Atlantic Type (4-4-2) Locomotive; Pennsylvania R. R.
Fig. 4. Pacific Type (4-6-2) Locomotive; Chesapeake & Ohio Ry.

Fig. 5. Pacific Type (4-6-2) Four-Cylinder Balanced Compound; A. T. & S. F. Ry.
Fig. 6. Mikado Type (2-8-2) Locomotive; Illinois Central R. R.
Fig. 7. 2-10-2 Type Locomotive; Baltimore & Ohio R. R.

(8 sq. metres) of grate area to burn anthracite coal. This locomotive, as also practically all modern engines of large size, is equipped with the Schmidt superheater.

Figure No. 3 shows the heavy Atlantic type locomotive of the Pennsylvania Railroad with 144,000 lbs. (60 tonnes) adhesive weight and a total weight of engine and tender of about 200 tons (180 tonnes).

The Pacific, or 4-6-2 type is illustrated by a Chesapeake & Ohio locomotive in Figure No. 4, with 180,000 lbs. (82 tonnes) on drivers, and a total weight of engine and tender of 221 tons (200 tonnes). This engine has nearly 3800 sq. ft. (353 sq. metres) of heating surface, in addition to which, the superheater furnishes nearly 900 sq. ft. (84 sq. metres) more.

Figure No. 5 shows the same general type of engine, but provided with four cylinders, making this engine what is known as a "balanced compound": the high-pressure cylinders being inside the frames, and set with the corresponding sides opposite to the cranks of the outside cylinders, thereby dispensing with a large amount of counterbalance, produce a very steady running machine. The cylinders in this case are 17½″ and 29″ x 28″ (444 and 736 x 711 mm.) stroke, the steam generating surface being about 3450 sq. ft. (320 sq. metres).

The Mikado, or 2-8-2 type of engine illustrated by Figure No. 6 was built for the Illinois Central Railroad, and while not the heaviest of this type, illustrates the adaptation of the long boiler and wide firebox, made possible by use of the trailing truck.

The 2-10-2 type is shown in Figure No. 7, and represents an engine with nearly 340,000 lbs. (154 tonnes) on the driving wheels; the total weight of engine and tender being 292 tons (265 tonnes). This engine has an exceptionally large boiler with nearly 5600 sq. ft. (520 sq. metres) of heating surface and over 1300 sq. ft. (120 sq. metres) of superheated surface in addition; the cylinders being 30″ x 32″ (762 x 813 mm.), giving a tractive force of 84,000 lbs. (38,000 kilos).

This probably represents the limit to which we can proceed in placing multiple driving axles in one frame, as the restrictions of curvature would be such that where more wheels are needed, we must either use an articulated locomotive, or special

arrangements in driving axles and rods, which allow the wheels to shift laterally and adjust themselves to the curvature of the track.

The type of articulated locomotive most commonly in use is that due to M. A. Mallet of Paris, and by means of this arrangement we are enabled to apply twelve, sixteen or twenty driving wheels to a single locomotive. In this type of locomotive, the boiler is secured rigidly to the rear of the H. P. set of cylinders and frames, and the front cylinders and frames support the front end of the boiler, but are arranged in a truck,

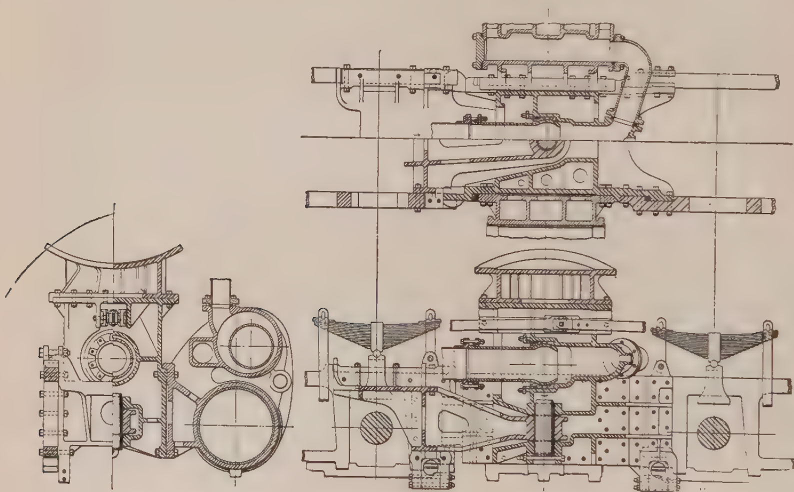


Fig. 8. Articulated frame connection of Mallet Locomotive, showing cast steel cylinder saddle, radius bar and frames.

so that they can swivel and swing cross-wise of the engine at the same time, the boiler support having a sliding surface for this purpose. The L. P. cylinders are located on the front, or swivel section, and therefore it is necessary to transmit only receiver pressure through the swivel or flexible pipe, which greatly reduces the expense and difficulty in maintaining the flexible joints.

Figure No. 8 shows the method of connecting the frames and the receiver pipe at the H. P. cylinder, so that the desired amount of flexibility will be obtained, and by placing the ball joint of the pipe immediately over the center pin, we secure

Fig. 9. Mallet Articulated Compound Type (2-6-6-2) Locomotive; Norfolk & Western Ry.

Fig. 10. Mallet Articulated Compound Type (2-8-8-2) Locomotive; Virginian Ry.

Fig. 11. Triplex Compound (2-8-8-8-2) Locomotive; Erie R. R.

the minimum amount of motion and also practically no extension or compression of the receiver pipe, due to the movement of the engine in rounding curves.

This type of engine was originally introduced for heavy pusher service, but it became so popular with some companies that numbers of them have been put into regular road service operating over an entire division. With such an engine, it is advisable to have a power reverse gear, as two valve motions must be operated by the engineer in reversing the engine.

Figure No. 9 shows a 2-6-6-2 Mallet locomotive of the Norfolk & Western, with 337,000 lbs. (152 tonnes) adhesive weight and 281 tons (255 tonnes) engine and tender. The water heating surface is over 5000 sq. ft. (465 sq. metres), with nearly 1000 sq. ft. (93 sq. metres) superheater surface additional.

Figure No. 10 shows a 2-8-8-2 locomotive, used on the Virginian Railway. This engine has nearly 480,000 lbs. (220 tonnes) on the driving wheels with a total weight of engine and tender of not quite 375 tons (340 tonnes), showing that less than two-thirds of the weight of the machine as a whole is available for adhesion.

There has recently been built for the Erie Railroad a locomotive, which is really an extension of the Mallet idea, and was proposed by the writer in order to obtain a still greater tractive force without seriously increasing the length or weight of the engine and its tender. This is illustrated in Figure No. 11, and it will be seen that it is of the 2-8-8-8-2 type, being a Triplex Compound of about 755,000 lbs. (340 tonnes) adhesive weight and about 425 tons (385 tonnes) total for the machine complete. With this engine, we have 90% of the total weight on the drivers, and are able to obtain a tractive force at the circumference of the wheels, when starting, of 160,000 lbs. (72,500 kilos), or, as compared with the 2-10-2 type locomotive shown in Figure No. 7, we have practically double the tractive force with 45% increase in weight.

In this locomotive, there are six cylinders, all of the same size, that is, 36″ in diameter x 32″ (914 x 813 mm.) stroke. The middle cylinders, with their frames, are fastened rigidly to the boiler, and are operated under high pressure. The exhaust from the high pressure cylinders is taken to the two front

low pressure and the two rear low pressure cylinders which, with their frames and steam pipes, are flexibly connected similar to the Mallet arrangement shown in Figure No. 8, thus giving a compound ratio of 2. While the steam from the front pair of cylinders passes through the smoke box and stack in the usual manner, that from the rear cylinders passes through a feed water heater and finally up an escape pipe at the back of the tank. There are about 6900 sq. ft. (640 sq. metres) of water heating surface and nearly 1600 sq. ft. (150 sq. metres) of superheating surface.

This engine is little longer or heavier than a Mallet of the same unit weight on driving wheels with its tender, the dead weight of the tender reducing the capacity of the train; in this case, the tender exerts nearly one-half as much tractive force as the two sections under the boiler, and so adds to the pulling power of the engine, and increases enormously the amount of train which can be handled with a single locomotive. While this engine has not been in service for a great length of time, yet its many advantages seem to point to it as a method of operating economy which may, for a while at least, avoid the expensive installation of electric locomotives for handling heavy freight traffic.

DETAILS OF CONSTRUCTION.

Cast steel is probably more closely connected with the development of the large locomotive than any other single item entering into its construction, and the possibility of being able to obtain large steel castings has taken much work from the blacksmith shop, and placed it in the steel foundry. Before the success of large steel castings, the main frames of American locomotives, for example, were made of hammered iron, entailing a great deal of heavy work in the blacksmith shop in hammering out the different sections and welding them together. The almost universal substitution, however, of cast steel for forging in locomotive frames and in the various cross braces, guide yokes and other parts, which had been formerly made of bar iron or steel, forged and finished to suit, has, in a great measure, reduced the importance of the blacksmith shop

in the manufacture of locomotives. This has become true to a large extent in connection with front and rear trucks and, as an example of the latter, may be illustrated the new trailing truck recently introduced by the Pennsylvania Railroad and which can be seen very clearly in Figure No. 3, and which is largely constructed of steel castings.

Alloy steels, and steels submitted to a final heat treatment after having been forged in the smith shop, have been introduced to some extent, more particularly in high speed and large locomotives, where it is important to decrease the weight of the individual parts. Piston rods and axles have been made with a central hole or core running from end to end, which reduces the weight, and assists in the process of heat treatment. It is probable that the full benefit of the higher elastic limit of such steels has not been taken advantage of, as in many cases the working stresses are maintained at the same figures as were used for ordinary carbon steel; but there is no doubt that as our familiarity with, and our confidence in, special steels increase, the various parts will be made still lighter by the use of higher working fibre stresses, and thus follow along the lines of European practice.

The reduction of weight in the reciprocating parts such as pistons, piston rods, cross heads and connecting rods, is of great importance on high speed locomotives which have a heavy load per driving axle, and by the intelligent introduction of proper metals and designs, it is possible to so reduce the effect of the counterbalance that a much larger static weight can be permitted to operate on rails and bridges of a given weight and strength. This is illustrated also in the E-60 locomotive of the Pennsylvania Railroad, shown in Figure No. 3, in which the weight on two pairs of driving wheels is 133,000 lbs. (60 tonnes); but as the dynamic augment per wheel, due to the counterbalance, at a speed of 70 miles (112 kilom.) per hour is less than 30% of the static weight on drivers, the effect on the track is not more injurious than many passenger locomotives which have considerably less weight per axle.

The Walschaerts valve gear has almost entirely superseded the Stephenson, which was formerly used, particularly in America. The reason for this change has been more in order

to make the gear accessible, to obviate the eccentrics which had reached enormous size due to the large driving axles which were necessary, and to give opportunity to provide substantial cross braces between the frames, than to improve the motion of the valve itself. Other valve gears have also been introduced recently, which are really different varieties of the Walschaerts or the Hackworth gears, but most of these are radial gears in which the lead is constant for varying percentages of cut-off, and it is considered by many that the actual motion of the valve is not as satisfactory as with the increasing lead due to the Stephenson gear. It has been reported, for instance, that engines with the Walschaerts valve motion will not start a train as rapidly as those fitted with the Stephenson gear; but the consequential advantages are so great that it is felt that this objection to the motion of the valve can be overlooked.

Piston valves have become so common that it is hardly necessary to dwell upon the fact that they have been almost entirely introduced within the last fifteen years. In many localities, the cylindrical type of tender is adhered to, one of the great features of this style being the ease with which the brake rigging and trucks can be inspected.

When we come to consider the changes that have taken place in the boiler, we find that the most notable one is that of size, as not only has the diameter increased to 100 in. (2.54 m.) in some cases, but the flues have also increased in length to 24 ft. (7.315 m.) and even, in some cases, to 25 ft. (7.620 m.). This has naturally led to improved methods of construction, such as the one-piece dome, drawn by hydraulic power from a single sheet, the introduction of the combustion chamber and several types of fire box with hot air flue, bridge walls, etc. Flexible staybolts are also being very generally used, in some cases not only in the "breaking zone", but for the complete equipment of fire box staybolts. These staybolts are of several different varieties, namely, those in which a portion is formed like a ball resting in a socket, others in which there is a hinge or knuckle joint in the bolt and still others which are formed of laminated sections, in order to permit bending with less stress in the bolt material.

ADJUNCTS AND SPECIALTIES.

The development of the locomotive, in the direction of increased weight and size, has brought about the addition of a number of special features, the necessity for which, a short time ago, would not even have been dreamed of. Many years ago, there were a few engines fitted with the power reversing mechanism, but these were soon abandoned as unnecessary with the small locomotives existing at that time. The articulated locomotive, however, with its two or three valve gears, has caused the return to the power reverse apparatus, and even large locomotives with a single set of driving wheels are often now so equipped.

Some of these power reversing mechanisms are operated by compressed air and some by steam, and there are different methods of locking the piston in place after it has assumed its position, as designated and controlled by the hand lever in the cab. One method is to use a cylinder of oil, which can pass freely from one end of the cylinder to the other when the mechanism is in motion, but which is locked by closing the ports when the desired position has been assumed. In another type, there is no oil cylinder; but any movement of the gear from the desired position opens the valve, and brings the piston back to the point at which it is intended to rest. Figure No. 12 shows such a reverse gear detached from the boiler, and these gears are powerful enough to move even the three, or rather the six, sets of valve motion used on the Triplex locomotive.

It is probable that no adjuncts which have been applied to the large locomotives have been as valuable as the superheater, which gives an economy in the consumption of coal and water, or an increased output, depending upon which is desired. It is necessary to reduce the steam generating surface when the superheater is applied, and if the amount of coal burned be reduced in proportion to the reduction in this heating surface, there will be a saving of approximately 25% in fuel for the same output of work. If it is desired, however, to burn the same amount of coal in the fire box as with a non-superheater locomotive of the same size, then the capacity of the engine will be increased 30% or more, and of course any com-

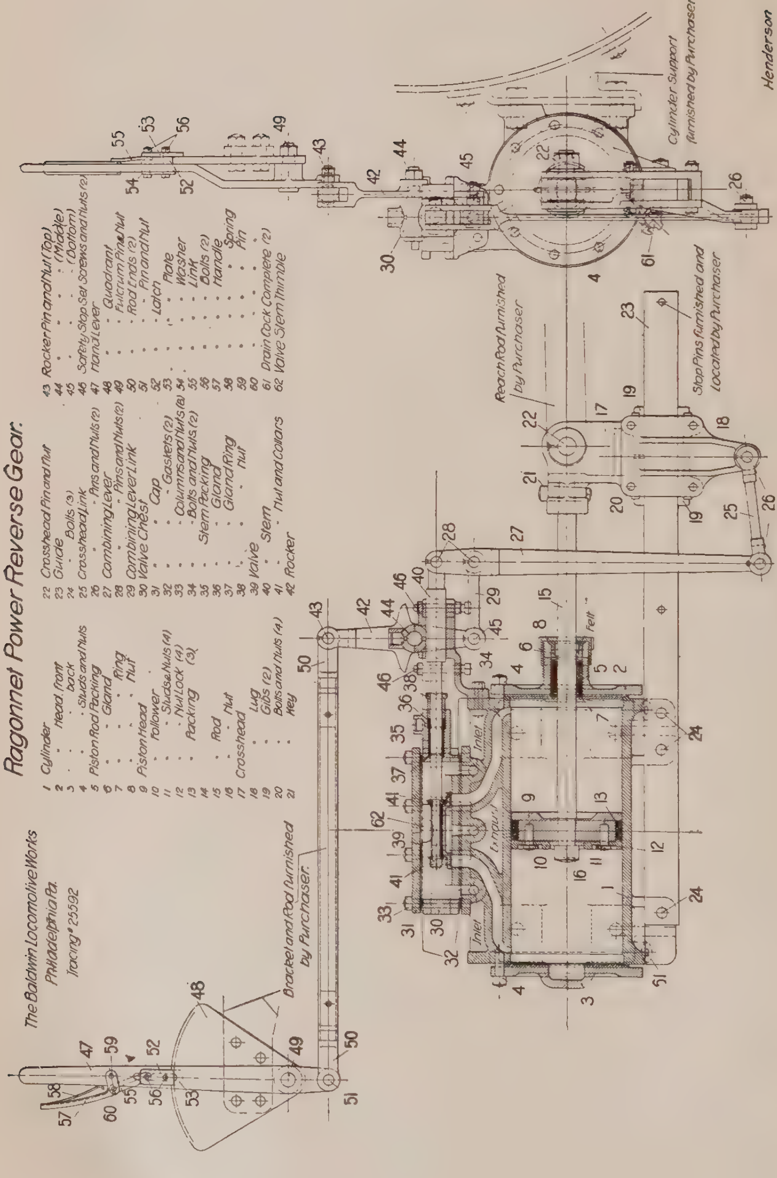
bination between these two values can be obtained. This shows at once that we not only get more work out of a pound of coal, but that we also save the fireman's efforts, as it is not necessary for him to shovel as much fuel into the fire box, for the same power, as with the saturated steam locomotive.

The arrangement of the superheater is so well known that it is not necessary to describe it in detail. As a general statement, it may be said that the superheating surface is in the neighborhood of 20% of the generating surface, and that the equivalent heating surface has often been taken as the steam generating surface plus one and one-half times the area of the superheating surface. With the proportions of a type of superheater frequently used, an amount of superheat from 150 to 250 degrees Fahr. (85 to 140 degrees Cent.) can be obtained above the saturated temperature, the corresponding volume of steam being increased about 16% for each 100 degrees Fahr. (55 degrees Cent.) of superheat.

With large locomotives, the superheater does not always sufficiently relieve the fireman of severe work, as it has been demonstrated that an ordinary man cannot keep up, for any length of time, a supply of coal in the fire box greater than from 5000 to 6000 lbs. (2300 to 2700 kilos.) per hour. There have been several methods introduced for lightening his work, such as automatic fire door openers, pneumatic grate shakers and coal pushers. The first of these can be seen in Figure No. 13, and is so arranged that a pressure of the foot when ready to throw coal into the fire box causes the door to open by air pressure, and the release of the pedal allows the door to close.

With large fire boxes, the shaking of grates has become quite a laborious operation, and steam or air cylinders have been substituted for manual labor to operate the grates. The movement required by the fireman is practically the same, that is, a small lever is operated, but as this controls a valve, the steam or air under pressure does the actual work of shaking the grate.

When the fuel in the tender is partly exhausted, it is necessary for the fireman to go back several steps for each shovelful. This has, at times, been obviated by placing a second man on the tender to pull forward the coal as the supply has been



The Baldwin Locomotive Works
Philadelphia Pa.
Tracing # 25592
Ragonnet Power Reverse Gear.
1 Cylinder
2 " Head, front
3 " " back
4 " Studs and Nuts
5 Piston Rod Packing
6 " " Gland
7 " " " Ring
8 " " " Nut
9 Piston Head
10 " Follower
11 " " Studs & Nuts (4)
12 " " Nut Lock (4)
13 " Packing (3)
14 " Rod
15 " " Nut
16 Crosshead
17 " Lug
18 " Gibs (2)
19 " Bolts and Nuts (4)
20 " Key
21
22 Crosshead Pin and Nut
23 Guide
24 " Bolts (3)
25 Crosshead Link
26 " " Pins and Nuts (2)
27 Combining Lever
28 " " Pins and Nuts (2)
29 Combining Lever Link
30 Valve Chest
31 " " Cap
32 " " Gaskets (2)
33 " " Columns and Nuts (8)
34 " " Bolts and Nuts (2)
35 " Stem Packing
36 " " Gland
37 " " Gland Ring
38 " " " Nut
39 Valve
40 " Stem
41 " " Nut and Collars
42 Rocker
43 Rocker Pin and Nut (Top)
44 " " " " (Middle)
45 " " " " (Bottom)
46 Safety Stop Set Screws and Nuts (2)
47 Hand Lever
48 " " Quadrant
49 " " Fulcrum Pin & Nut
50 " " Rod Ends (2)
51 " " Pin and Nut
52 " " Latch
53 " " " Plate
54 " " " Washer
55 " " " Link
56 " " " Bolts (2)
57 " " " Handle
58 " " " Spring
59 " " " Pin
60
61 Drain Cock Complete (2)
62 Valve Stem Thimble
Bracket and Rod furnished by Purchaser.
Reach Rod furnished by Purchaser
Stop Pins furnished and located by Purchaser
Cylinder Support furnished by Purchaser
Inlet
Exhaust
Felt
Henderson

Fig. 12.

reduced; but the pneumatic coal pusher shown in Figure No. 14 has obviated the necessity for that labor, and as this device is under the control of the fireman, the coal can be pushed forward whenever it is desirable to decrease the distance from the fire door to the coal pile. This apparatus is shown in the quiescent and in the active positions for which it is intended to do the work.

Even these devices are not always sufficient, and therefore a stoker or mechanical fireman has been developed, which actually takes the coal from the tender and deposits it on the grate. There are two principal varieties of stokers; one which distributes the coal on top of the fire, similar to the usual method of hand firing, and the other by which it is fed underneath. Figure No. 13 shows some of the piping and arrangements of the Street stoker, which is of the former type; but many engines have been equipped with the Crawford stoker, which pushes the coal forward underneath the burning surface, and so gives a partial coking effect before the fuel itself becomes ignited. With such mechanisms, it is possible to deliver from five to eight tons of coal per hour, which is greater than has so far been found necessary to supply fuel even to the largest locomotives.

Another method of reducing or practically eliminating the labor of the fireman, is to burn fuel oil instead of coal, and in some localities this has the advantage of also decreasing the cost of operation. This method was first introduced in Russia in the Caspian district oil fields, and has in this country been very largely followed in California and Texas, where the price of oil was cheap and the cost of coal excessively high.

When oil is used as fuel, it is blown into the fire box by means of a steam jet which atomizes it to such an extent that it burns practically like a gas. With the proper attention, steam can be maintained without smoke, except once or twice an hour when it is necessary to ''sand'' the flues, in order to clean out the carbon deposits. In addition to the saving in cost where oil is cheaper than coal, it has been found possible to generate greater quantities of steam in the same fire box, so that while we normally assume that each sq. ft. (sq. metre) of heating surface in a coal burning locomotive will produce 12

lbs. (60 kilos.) of steam per hour, it is possible to reach 18 lbs. (90 kilos.) of steam per sq. ft. (sq. metre) of heating surface per hour in an oil burning locomotive.

This fuel is ideal for large locomotives, as it requires practically no handling, and the quantity can be regulated to a nicety; but on the other hand, in many sections of the country the cost will be prohibitive, and if it were used to any great extent, the price would no doubt be even further increased, so

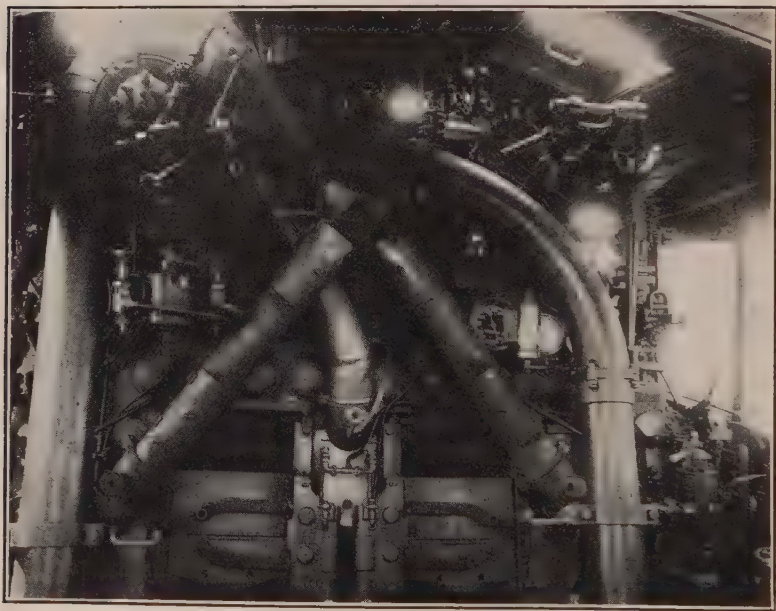


Fig. 13. Piping and arrangement of Street Stoker.

that it is not likely that it will ever become a competitor of coal for general service.

The burning of coal dust under steam boilers is very attractive, but has not yet proceeded far enough to state the possibilities of satisfactorily using coal dust in a locomotive. For heating furnaces and for steel making, it produces admirable results, but it will no doubt require considerable experimenting before it is satisfactorily burned in a locomotive fire box. It probably will be necessary to depart from our con-

ventional ideas of locomotive fire box construction in order to satisfactorily burn powdered coal; but the field for this is so great that we believe it is only a question of time, and that a short one, when it will be found to respond satisfactorily to locomotive requirements. This, like fuel oil, would reduce the

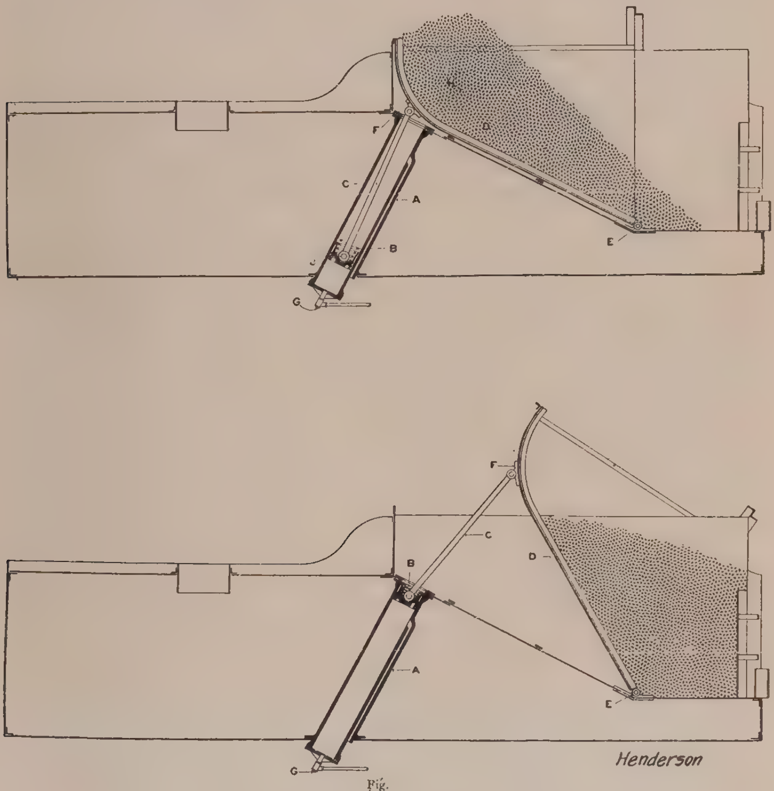


Fig. 14. Pneumatic Coal Pushing Device for Tender.

labor of the fireman to a very small amount, and it is certainly a method that is greatly to be desired, especially with the large locomotives now being constructed, and which will, no doubt, be constructed during the coming decade.

The internal combustion engine has been applied to locomotives to a limited extent. With small units in which trans-

mission can be treated like an automobile, with change gears and chain transmission, the results have been fairly satisfactory, but the application to large locomotives, which must generate and use from 1000 to 2500 horsepower, is a very difficult problem, especially as the tractive force at low speeds must be great in order to produce satisfactory traffic characteristics, and much experimental work will be necessary before this can be accomplished.

DISCUSSION

Mr. Eaton. **Mr. G. M. Eaton,*** Mem. A. I. E. E., said that he had great confidence in the future of steel submitted to a final heat treatment; that he looked for a great increase in the use of such steel for reciprocating parts; that while the present price was high it would decrease with the use of newer methods of manufacture.

Referring to the author's statement that the use of the 2-8-8-8-2 type recently built for the Erie Railroad might result in such operating economy as to defer the installation of expensive electric locomotives for handling heavy freight, he said that he could not help a feeling of satisfaction at this recognition of the electric locomotive. In service electric locomotives have solved problems that steam locomotives have failed to solve as satisfactorily.

Electrification is expensive, and if some alternative is cheaper, then electrification is an expensive luxury. In some cases, however, it is becoming an expensive necessity.

The Mallet locomotive shown in Fig. 9 was replaced by an electric locomotive on the Bluefield Division of the Norfolk & Western Railway. Three of these Mallet locomotives (840 tons) were used to haul a load of 3000 tons in winter and 3300 tons in summer up a 2% grade at a speed of 7 miles per hour. The same train of 3300 tons is now hauled by two electric locomotives (540 tons) up the same grade at 14 miles per hour, winter and summer.

Mr. Stillman. **Mr. Howard Stillman,**** Mem. Am. Soc. M. E., in response to the statement that the Newport News Company was using oil as a fuel successfully without an atomizing device, using 200 lb. per sq. in. pressure, and the question whether this could be used on locomotives, said that it was a question of the ultimate cost of the power necessary to atomize the oil. Oil must be atomized by some power. The Southern Pacific Company used steam because of its cheapness and simplicity.

In response to questions by Mr. Stucki, Mr. Stillman said that his experience in attempting to lighten up reciprocating parts by the use of alloy steel had been a very expensive one. He did not wish to criticize the principle, but the subject was very new and the methods as yet somewhat crude.

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* Engr., Railway Division, Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
** Engr. of Tests, Southern Pacific Co., San Francisco, Calif.

That in utilizing the weight of the tender to increase the tractive power, as in the 2-8-8-8-2 type, the cost of the machine was very great, and it was a question of whether or not the power developed would pay for the cost. Also in the use of the two-unit Mallet type, both units are tied up during repair to one unit, and that the net economy must be considered. Mr. Stillman.

That the superheater was all that was claimed for it; it had gotten beyond the stage of uncertainty and had come to stay. He could verify Mr. Henderson's figures.

Mr. F. J. Cole,* Mem. Am. Soc. M. E. (by letter), said that locomotives of the weights and power in daily use at the present time would have been considered impracticable 15 or 16 years ago. The increase in weight and capacity of locomotives in the United States has advanced much more rapidly than would have been imagined possible a few years ago. This rapid advance is largely due to the improvements which have taken place in the strength of track and bridges and to the general use of freight cars of 50 tons capacity or over making the economical use of such locomotives practicable. Mr. Cole.

With the restrictions imposed by the height and width, it was inevitable that the increase should take place in the third dimension, namely, length. Had it not been for the great improvements in appliances which have come into general use in recent years, such as superheaters, stokers, outside valve gear, etc., it would not be possible at the present time to operate such large units. The application of superheaters to locomotives has reduced the amount of coal burned, as compared to similar work with saturated steam. Mechanical stokers, by increasing the amount of coal which may be fed per hour into a locomotive firebox, have done much toward promoting the economical use of large locomotives.

The Mallet articulated locomotive, since the first large one of its type was built in this country by the American Locomotive Company for the Baltimore & Ohio Railroad in 1904, has been taken up enthusiastically by American railroad managers, not only for the economical hauling of freights on long, heavy grades, but for road service as well. One large road has in general service one hundred 2-6-6-2 class.

This type of locomotive, as originally designed by Anatole Mallet, was intended for narrow-gauge military roads, which could be laid following the undulations of the surface of the ground with sharp curvature and the minimum amount of grading. The inherent advantages of this type consist of distribution of power between two engines, flexibility, and greater tractive power without increase in individual axle loads. It is adapted to the heaviest freight service in the world, and performs satisfactorily the exacting requirements of American railroad operation.

The Mallet is naturally a compound proposition, since the engines are generally employed for heavy grades, which if operated with simple engines would use steam wastefully on account of the long cut-offs and

*Chief Consulting Engineer, American Locomotive Co., Schenectady, N. Y.

Mr. Cole. comparatively short range of expansion. The low-pressure cylinders are supplied with steam by means of a swinging receiver pipe provided with ball joints at the back end, which with steam of comparatively low pressure are easily maintained and give no trouble in actual service. In addition to this the advantage of dividing the power into two engines is of considerable advantage in surmounting heavy grades, for the reason that when one engine slips the other will usually hold and keep the slack of the train up until the pressure in the receiver increases or decreases; for the engines, if they slip at all, are apt to slip alternately, and rarely, if ever, at the same time. Furthermore, there is no direct sequence of the operation of the cranks on the forward and back engines, thus tending to make the power more uniform during one revolution.

Regarding the triplex compound type, it is probable that the steaming capacity is the determining factor in the successful operation in an engine of this kind. It is possible to conceive of a situation where by reason of slow speed requirements an engine of this description can be used successfully; for instance, in pusher service the amount of horsepower really required is much smaller than if the engine were operated in road service. Under these conditions, by reason of its much greater tractive power, it is possible that an engine of this kind could be operated successfully.

For general purposes it is, of course, a question whether a boiler of sufficient size can be made to supply the increased amount of steam necessary to operate two additional cylinders, especially when half the steam which is ordinarily used for exhaust purposes in producing a vacuum in the steam chest is diverted to a feed-water heater and blown out through the auxiliary stack at the back of the tank. Mr. Henderson has shown how the steaming capacity is improved by using a trailing truck, comparing a 2-8-0 with a 2-8-2 type. The reason, apart from the construction permitting a deeper firebox, is that the adhesive weight has become a smaller percentage of the total; therefore, the boiler of the 2-8-2 type is larger and its capacity for generating steam is greater. Using such a large percentage of total weight of engine on the drivers and adding to this most of the tender weight, necessarily increases the available adhesive weight without any increase in boiler capacity; therefore, the use of such a design is limited to very slow speeds and relatively small horsepower requirements.

In connection with the general use of the Walschaert valve gear in the United States, it is interesting to note that the principal advantages of this gear are greater accessibility and, what is much more important, lower maintenance cost, the principal maintenance item consisting of an occasional renewal of pins and bushings. It is probable that the Stephenson motion, when new, gives a slightly better distribution, in which the essential features of a successful gear are naturally obtained without any great difficulty. This is of but little actual importance, however. If care is taken in designing the Walschaert valve motion, as for instance in seeing that at least the same percentage of maximum cut-off is obtained

necessary for starting trains easily, and if the lead (which is constant on the Walschaert gear) is so adjusted as to be suitable for the service, it has been abundantly proved that the Walschaert valve motion will start and operate a train as rapidly and as economically as one fitted with the Stephenson gear. One of the principal difficulties with Stephenson gear was the maintenance and wear of eccentrics, which in many instances was so excessive that the motion was very soon distorted and required constant adjustment and re-setting. On the other hand, many large railroads require that the Walschaert gear be fitted up without adjustments, and any changes required must be by a blacksmith; that is, it requires upsetting or lengthening in a forge before the adjustment can be changed. Mr. Cole.

Crude oil burned in a locomotive firebox to generate steam is a very wasteful practice compared with the amount required for the same horsepower if burned in the cylinders. As yet, no design has been produced which will give the steam locomotive's characteristics of flexibility at all speeds, simplicity, great starting power and economy in construction. The problem from an engineering point of view still remains to be solved.

Paper No. 91

ROLLING STOCK OTHER THAN MOTIVE POWER.

By

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This paper will briefly deal with the car equipment used by the railroads of the United States of America and Canada. It will principally point out the improvements made in this direction during the last decade.

Since practically all the railroads in the United States are private roads, and since all but one system in Canada are operated by private companies, a healthy competition exists between the different lines. However, the rates for all the traffic are regulated by the respective governments, hence, the competition has mainly centred itself on improvements in the rolling stock, and this is the reason why a most phenomenal advancement in the construction of all cars, passenger as well as freight, took place.

The specific objects in these improvements are numerous and may be grouped as follows:

Safety and comfort of passengers
Strength and efficiency of construction
Efficiency in handling freight
Efficiency in moving trains
Protection of freight

Safety and Comfort of Passengers.

The desire to improve the conditions as to safety and the great efforts of various leading roads have brought about an evolution hardly dreamed of ten years ago. This was accomplished by the use of steel instead of wood in the construction of our passenger train cars, which renders them fireproof from

outside and from inside, and in case of a wreck prevents the splintering of the material, previously found so disastrous. This holds true for all kinds of passenger train cars, Mail, Baggage and the Pullman sleeping cars included. Regarding comfort, equally as much has been accomplished, and the lighting, heating and ventilating systems have been brought up to such a state of efficiency as to provide perfect comfort to the traveling public.

Strength and Efficiency of Construction.

This object has led to the use of steel in the construction of freight cars, and has induced a most careful distribution of metal so as to get a strong, still least expensive, car.

Efficiency in Handling Freight.

Especially in the handling of bulky freight, such as coal, ore, cinders, etc., great progress has been made by the various roads. With this in view, the respective cars have been made self clearing and the door-operating mechanisms designed to work quickly and safely. As a striking example may be mentioned the up-to-date ore car, which has been developed to such a degree that the loads are dropped and the doors brought back in approximately one tenth the time required ten years ago. Besides all that, it takes fewer men per car, reducing the cost of handling enormously. Aside from this, it naturally increases the capacity of the ore docks in the same proportion and allows the cars to be in actual service a greater portion of the time.

Under this heading we may also mention the coal-car unloading machines at the various docks, the special warehouse facilities and the Rules of Interchange adopted by the various roads, so that a carload shipment can proceed to destination without unloading.

Efficiency in Moving Trains.

With this point in view, the railroads have increased the capacity of their freight cars step by step, so that the 50-ton car is no more the latest standard. For heavy compact freight, 70-ton cars with 6-in. by 11-in. (15.24 x 27.94 cm.) journals are now being used. This not only lessens train resistance but it also makes it possible to reduce the percentage of dead weight to paying load. The time for a hundred-ton standard car is no doubt fast approaching.

For the same reason the tonnage in each train has gradually been increased, so that a train of one hundred 50-ton loads is not uncommon on coal roads.

Protection of Freight.

Great efforts have been put forth in this direction. For all house cars an absolutely weatherproof construction has been considered most essential and has led to a number of improved roof constructions.

The leakage of grain is more and more overcome by proper application of the lining and will eventually entirely disappear with the use of steel-sheathed cars.

For perishable freight, such as fruit and vegetables, a weather-proof, still thoroughly ventilated car, has been brought out by roads engaged in this particular business.

Many efforts have been made to get a reliable box-car door, one that is tight when closed and easily operated, one that will not get out of order and cannot be "picked" by intruders. The saving effected by these different methods of protecting the freight amounts to hundreds of thousands of dollars every year.

MASTER CAR BUILDERS' ASSOCIATION.

It is well known that this great progress is, to a very large extent, due to the Master Car Builders' Association, a mutual organization of the railroads on this continent.

It revises from time to time the rules of interchange, so as to expedite the movements of the through traffic; and it establishes standard designs and specifications for materials, details and constructions which have been thoroughly tried out, and the adoption of which is considered beneficial to all. So far the following standards have been adopted:

Adjusting height of couplers,
Air-brake and train air signal instructions,
Air-brake appliances,
Air-brake hose couplings and gaskets, dimensions of,
Air-brake defect card,
Air-brake hose gaskets, specifications for,
Air-brake hose, specifications for,
Air-brake hose, woven and combination woven and wrapped, specifications for,
Air-brake tests, code of,

Air-brakes, general arrangement and details,
Air-brakes, cleaning and testing of,
Arch bars, column and journal-box bolts,
Automatic coupler,
Automatic coupler, specifications for,
Axles, design of,
Axles, steel, specifications for,
Bolt heads,
Brake beams,
Brake chain,
Brake head,
Brake-head gage,
Brake shoe,
Brake-shoe gage,
Brake shoes, specifications for,
Brake staff, height of,
Brake-staff carrier iron,
Car sills, uniformity of section of,
Catalogues,
Center plates,
Cleaning and testing air brakes,
Code of air-brake tests,
Contour and limit gages for automatic coupler,
Coupler, automatic, specifications for,
Coupler butt,
Coupler shank,
Coupler head,
Couplers, height of,
Coupler yokes,
Couplings, air-hose, dimensions of,
Diameter of steel and steel-tired wheels,
Distance between backs of flanges,
Door fixtures, side,
Drop-test machine,
Dust guards, dimensions of,
End for hopper-door operating shaft,
Flooring,
Followers,
Form of wheel tread and flange,
Front and back coupler stop,
Gage for worn couplers,
Gage, limiting outline, for brake beams,
Gages for coupler and yoke,
Gaskets, air-hose, dimensions of,
Guard arm,
Guard rail and frog wing gage,
Height of brake staff,

Spacing between coupler horn and buffer beam,
Specification paper,
Specifications and tests of brake beams,
Specifications for air-brake hose,
Specifications for automatic couplers,
Specifications for brake shoes,
Specifications for knuckle pivot pins,
Specifications for separate knuckles,
Specifications for tank cars,
Specifications for woven and comb. woven and wrapped air-brake hose,
Splicing of sills,
Square bolt heads,
Steam and air connections for passenger cars,
Striking horn,
Tank cars, specifications for,
Temporary standard coupler-head,
Terms and gaging points for wheel and track,
Testing and cleaning air-brakes,
Testing machine for knuckle pivot pins,
Uniformity of section of car sills,
Wheel-check gage,
Wheel circumference measure for cast-iron wheels,
Wheel-defect gage,
Wheel-flange thickness gage for new wheels,
Yoke rivets.

Great care is being exercised that nothing is made standard without first being thoroughly tried out for a number of years. During this period the prospective standard is listed under "Recommended Practice". At the present time we find the following items in this class:

Air and steam connections for passenger cars,
Air-brake appliances,
Air-brakes, general arrangements and details,
Area of bearing surface of lock on coupler wall,
Area of lock bearing surface on tail of coupler knuckle,
Axle drop test,
Axles, iron, specifications for,
Bolsters, cast and pressed, gages for,
Bolsters, cast steel, specifications for,
Box-car end, design and strength,
Brake-beam details,
Branding steel wheels,
Center sill, minimum design requirements,
Chain, specifications for,

Check chains,
Circumference measure for steel and steel-tired wheels,
Classification of cars,
Collection of salt-water drippings,
Couplings, steam-hose, specifications for,
Couplers, uncoupling arrangements for,
Design and strength of box-car ends,
Dimensions, inside, of box cars,
Dimensions, limiting, for cast-steel truck sides,
Door fixtures, end,
Electric-train lighting, specifications for,
End-door fixtures,
End-door seal records,
Examination of car inspectors, rules for,
Fastening for tires, steel-tired wheels,
Flange and tread, steel and steel-tired wheels,
Framing for box cars,
Gage for measuring thickness of rim of steel wheels,
Gage, plane, for solid steel wheels,
Gage, rotundity, for solid steel wheels,
Gages for cast-steel truck sides,
Gages for cast- and pressed-steel bolsters,
Gages, limit for round iron,
Heat-treated knuckle pivot pins, specifications for,
Height and width of cars,
Height of floors, refrigerator cars,
Helical springs, specifications for,
High-speed foundation brake-gear for pass. service,
Hose couplings, steam, specifications for,
Hose, steam, specifications for,
Ice tanks, refrigerator cars, capacity of,
Inside dimensions of box cars,
Inspectors car, rules for examination of,
Iron bars, wrought, refined, specifications for,
Knuckle pivot pins, heat-treated, specifications for,
Limit gages for round iron,
Limiting dimensions for cast-steel truck sides,
Lining for outside framed cars,
Lumber specifications,
Mounting tires,
Mounting wheels,
Pipe, welded, specifications for,
Placard boards for house cars,
Plane gage for solid steel wheels,
Platform safety chains,
Refined wrought-iron bars, specifications for,
Rotundity gage for solid steel wheels,

Rounding corners of doors, door jambs, etc., of stock cars,
Rules for examination of car inspectors,
Safety chains for steel and wooden freight cars,
Safety chains, temporary,
Salt-water drippings, collection of,
Seal records of box car end doors,
Sizes and dimensions for solid steel wheels,
Specifications for cast-iron wheels,
Specifications for cast-steel bolsters,
Specifications for cast-steel truck sides,
Specifications for chain,
Specifications for electric-train lighting,
Specifications for heat-treated knuckle pivot pins,
Specifications for helical springs,
Specifications for iron axles,
Specifications for lumber,
Specifications for refined wrought-iron bars,
Specifications for solid wrought-steel wheels,
Specifications for welded pipe,
Springs and spring caps,
Springs, helical, specifications for,
Stake pockets, longitudinal spacing of,
Stake pockets, permanent,
Stake pockets, temporary,
Steam and air connections for passenger cars,
Steam-hose couplings,
Steam hose, specifications for,
Steel tires, minimum thickness for,
Strength and design of ends of box cars,
Tire fastening for steel-tired wheels,
Tires, mounting of,
Tires, steel, minimum thickness of,
Train lighting, electric, specifications for,
Tread and flange for steel and steel-tired wheels,
Truck sides, cast-steel gages for,
Truck sides, cast-steel, limiting dimensions,
Truck sides, cast-steel, specifications for,
Uncoupling arrangements for couplers,
Welded pipe, specifications for,
Wheel circumference measure for steel and steel-tired wheels,
Wheels, cast-iron, designs of,
Wheels, cast-iron, specifications for,
Wheels, mounting of,
Wheels, solid steel, sizes and dimensions for,
Wheels, solid wrought steel, specifications for,
Width and height of cars,
Wrought-iron bars, refined, specifications for.

Even after a standard has been adopted as such, the progress in this specific item is not entirely checked, and as soon as something else has proven to possess sufficient merit, the original standard is revised or dropped.

For this same reason the railroads as a whole do not favor one standard design for each kind of car. It is true, this would reduce the first cost considerably and would simplify a great many other things, but it also would at once discourage further progress, the result of which is, as we know, stagnation.

A good deal of equipment also runs in special service, the conditions of which vary in the different parts of the country, hence, the railroads so far have considered it preferable to standardize detail parts only. By this they have in view details common to all cars, specifications of material, certain cross sections of rolled steel, so as to facilitate subsequent repairs, etc., and it is this wholesome combination of conservative standardization and progressive spirit which undoubtedly is responsible for the utmost efficiency of our railroads.

DEVELOPMENT OF SPECIAL PARTS.

There are a large number of firms and specialists engaged in the manufacture and improvement of detail parts which, in the aggregate, help greatly in making the rolling stock so efficient. The car companies themselves come, in a sense, under this heading, inasmuch as they make a specialty of building cars. They equip themselves with the most improved special machinery, and great credit is due them for the development of the steel-car designs of today and for the speed and accuracy of their work.

The air-brake companies now have perfected their devices so that a train running at sixty miles per hour can be stopped within a thousand feet, and the electro-pneumatic brake has already established itself on the subway trains and the passenger equipment of our foremost railroads. We undoubtedly will have to look for a similar ultimate solution in the handling of our ever increasing freight trains, as only in this way can a simultaneous application throughout the whole train be hoped for.

The coupler manufacturers year by year have improved this detail, and the couplers now operate successfully under the most unfavorable conditions and without it ever being necessary for the operator to go between the cars. All makes are interchangeable with one another as far as the coupling is concerned, but the construction varies widely. The M. C. B. Association is now working on one standard freight-coupler construction, combining the best features of the different existing makes, at the same time allowing sufficient surplus strength to take care of the future requirements for some time to come.

In lighting passenger trains, oil, ordinary gas and carburetor systems are fast giving way to electricity. Here three methods have been used, namely, a separate steam-driven dynamo in the baggage car, storage batteries or an axle-driven dynamo for each car. The latter is now mostly used, being very economical, especially since an overproduction of current during the run can be stored up for use in yards and on sidings. Acetylene has not been used to any great extent and most likely will not be until safer methods of handling it have been devised.

Many manufacturers make a specialty of body bolsters, truck bolsters, truck sides, transoms and sometimes of the complete truck, which enables them to procure special machines so as to manufacture with more speed, more accuracy and less cost, at the same time turning out a superior product. Of late a great deal of cast steel is being used in the construction of the articles mentioned.

The manufacturers of draft-gears deserve a great deal of credit for their untiring efforts in procuring a device which will absorb a large proportion of the shock and which will stand the severe service of today. Spring gears have almost entirely given way to the friction gears, inasmuch as the capacity required is often above 200,000 lbs.

Many firms have for years worked on the problem of assisting the truck in swivelling freely on the curves, so as to save the wheel flanges, rails and power, and they have in this endeavor brought out frictionless side bearings which, in their latest designs, now fully meet this task.

Brake beams, journal boxes and hundreds of other details and adopted standards are now being manufactured by indi-

vidual companies, who concentrate their energies in specific lines and have equipped their shops especially for such details. This way they can produce a better article for less money, and, besides that, assist materially in a systematic, quick and efficient way of building cars.

The wheels are cast of iron or steel or are rolled or forged of medium-high-carbon open-hearth material. By far the greatest number are of cast iron, chilled, and by using special mixtures and live material, good results have been obtained even under the heavy capacity cars. None the less, the strife for utmost safety and the ever increasing severity of the service conditions call more and more for rolled or forged wheels.

PASSENGER-TRAIN CARS.

Farsighted railroad officials for years have realized the danger of wooden passenger equipment, both as to fire and the splintering of the timber in wrecks, and they have realized right along that the passengers as well as the postal clerks and their own employees should be protected.

With this in view the Erie Railroad, in 1904, had two all-steel passenger-train cars built. One was a baggage car as shown in Fig. 1, while the other one was for express. The underframes consisted of two fish-bellied centre and two light side sills, the latter in connection with the eave members and the steel side plates formed an effective truss. At the doors these top and bottom members were reinforced to compensate for cutting the side sheets. The roof was built with the usual upper deck and covered with sheet steel, while the lining was made of boards. Shortly after the cars went into service, this wooden lining was replaced by fireproof composite boards so as to make them safer against fire and still to protect them against noise and all abnormal temperatures, and in 1907 both were converted into postal cars. They have been running in that service ever since.

The next step was taken by the Southern Railway, who, in 1906, had a lot of special passenger cars built with a view of protecting the passengers against collisions. For this reason the car sides below the window sills were made of steel, while everything above that line was built of wood, as heretofore,

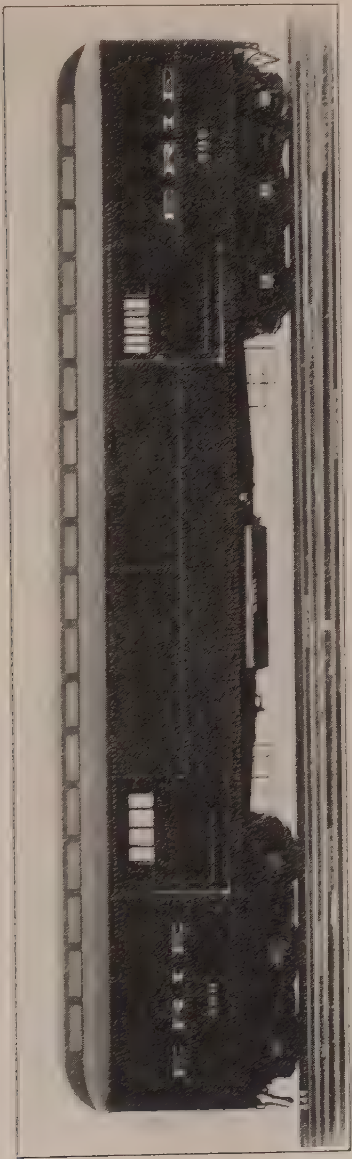

Fig. 1. Erie Baggage Car.

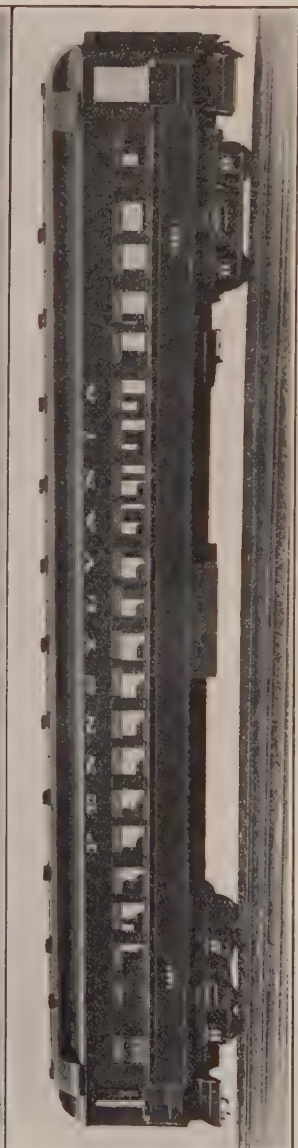

Fig. 2 (Upper). Southern Ry. Passenger Car.
Fig. 3 (Lower). Pennsylvania Steel Passenger Car.

except the posts and carlines, which were bent angle irons. The underframe consisted of two pressed and reinforced fish-bellied centre sills and the floor of a 1/8-in. (3.175 mm.) steel plate. On top of this sheet were two thin courses of wood with a thin layer of paper felt between them, and a final cover of linoleum on top of all, making a strong and easy floor. Such a steel construction below the window sill was used to get a car which would be well able to resist shocks in collisions. See Fig. 2 and Am. Engr. & R. R. Jour., July 1906.

In the following three cases of all-steel cars, the centre sills were made of straight rolled I-beams reinforced by truss rods:

The Southern Pacific built such a passenger car in the latter part of 1906. The roof was made without an upper deck, which soon assumed the name of arch-type roof. The outside sheathing was all-steel and the inside finish was wood. The floor was exceptionally strong, consisting of the following materials, beginning at the bottom: A light steel plate, a layer of mineral wool, regular tongue and groove floor boards, a thin steel plate, a thin layer of asbestos and 3/8-in. (9.525 mm.) linoleum. See Am. Engr. & R. R. Jour., January 1907.

The same road in the forepart of 1907 built a similar all-steel postal car. The centre sills again were trussed, the roof an arch type, but the lining was now made of asbestos. The floor was also changed, consisting of two corrugated steel sheets with two layers of hair felt between them and a monolithic cement floor laid on top of the upper sheet. See Am. Engr. & R. R. Jour., July 1907.

During the same time the Pullman Company built their first steel sleeping car. The centre sills were also trussed and the car sides from the windows down were formed of 1/4-in. (6.35 mm.) steel sheets. In this way a load-carrying girder of about 30-in. (.762 m.) depth was obtained. The top chord of this girder was a continuous flat bar, extending the whole length of the car, with the posts offset to get a smooth outside appearance. The bottom chord of this girder consisted of an angle-iron side sill. The floor construction was made double, the false floor below and the regular corrugated floor sheet inclosing a space which was filled with deadening material. The top of the corrugated sheet was finally covered with monolithic

cement. The lining also being metal and two thicknesses of asbestos board having been inserted between it and the sheathing all the way up and from end to end of car rendered it immune against fire, noise or weather and made a safe car to resist collisions. The name given this first steel sleeper was "Jamestown" and it was exhibited at the Jamestown Exposition. See Am. Eng. & R. R. Jour., April 1907.

After a period of experiments, study and developments, the Pennsylvania Railroad Company brought out their present standard steel passenger-car design and ordered two hundred of them to be built. The first one was completed and put into service in 1908. Now more than two thousand are in existence.

The car combines safety against wrecks and protection against noise, heat and cold. It is fireproof from inside and from outside, resembles the standard wooden coaches as to upper deck, and measures 70 ft. 5¾ in. (21.482 m.) over the body.

The underframe consists of two 18-in. (45.72 cm.) channels with top and bottom cover plates, forming a strong box-girder centre construction, which is well able to take the end shocks. The side sills are heavy angles, which, in connection with the lower sheathing and the continuous belt rail form a strong girder about 30 in. (76.2 cm.) deep. The belt rail is of a special section, so as to have the proper shape to form the window sills and to be rivetted to the outside of the sheathing without spoiling the appearance of the car. In this way the offsetting of the posts is avoided.

Another specific feature consists in the subdivision of the underframe into three nearly equal parts by two deep cross bearers, so as to increase the carrying capacity and to reduce the deflection of the car as a whole, without the use of additional material. With this arrangement the load is carried by the side truss to the outside of the deep cross bearers and end sills, and through these members to the centre sill, which in turn transmits the load to the centre-plate located about half way beween end sill and cross bearer. The usual body bolster is therefore dispensed with and a light side-bearing support takes its place, and the long span with its annoying deflection is also overcome, thereby avoiding one source of leaky roofs at the eaves.

The head lining is of composite board and the side lining of thin steel sheets, insulated by pasting asbestos boards to their hidden surface. The floor is formed of corrugated steel with plastic cement filled in on top. Some distance below, an asbestos board supported by a galvanized-steel sheet forms a sub-floor.

The ventilating and heating systems are the same as on their standard wooden passenger cars, taking air in at the top of the car and bringing it between the two floors along the side of the car, where it is heated by steam. The air, with doors and windows closed and with the ventilators on the roof wide open, can be completely changed in four minutes.

The whole car is designed so that it can roll over without danger of collapse, and care was taken that the centre line of the draft-rigging came within the cross-sectional area of the centre sill instead of underneath, as is the practice now on wooden cars. See Figs. 3 and 4.

Actually the same construction and the same size of cars are being used by the Pennsylvania Railroad Company for their Baggage, Mail and Dining Cars; and whenever side doors are required, they are located near the deep cross bearers, where the bending moment in the side truss is a minimum. In this way no special reinforcements are required to make up for the cutting of belt rail and the sheets.

Their suburban cars are of similar construction but have a lighter centre sill and are considerably shorter. The trucks and roof constructions are arranged so as to admit electrical equipment whenever this method of locomotion is adopted.

A mail car of similar construction and built for the Chesapeake & Ohio Railway is shown in Fig. 5. It is of steel throughout, except the floor. It has fish-bellied centre sills, a rolled channel with flanges downward for the eave member, and the belt rail consists of a flat bar on the outside of the steel sheathing. The interior of the car is made to suit the requirements of the Post Office Department and is clearly shown in Fig. 6.

Since the "Jamestown" sleeping car was built, many improvements have been made by the Pullman Company in their present standard sleeping car, as shown in Fig. 7. Fish-belly centre sills have taken the place of the trussed sills; Z-bar

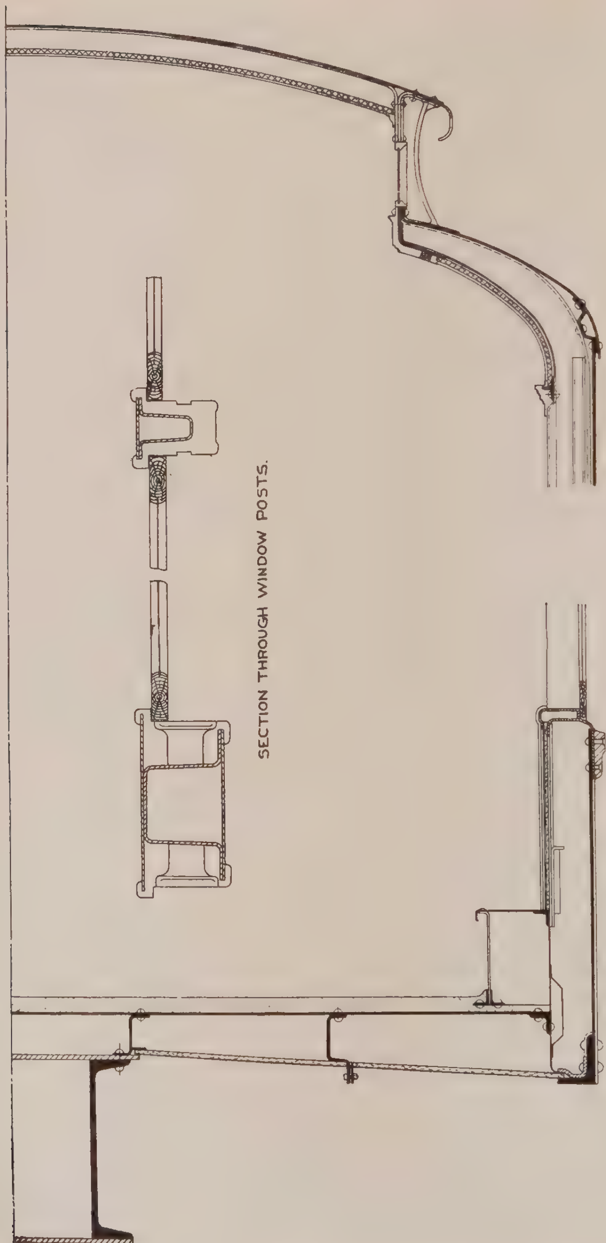

Fig. 4. Cross Section of Pennsylvania Steel Passenger Car.

Fig. 5. Chesapeake & Ohio Mail Car.

side sills, $\frac{1}{8}$-in. side sheets and an angle-iron belt rail form the side truss; and the interior lining and fixtures are made of pressed steel, grained and finished.

In the beginning of the current year the Erie Railroad had a lot of suburban cars built in which the load-carrying side truss differs completely from the heretofore adopted forms. It is made up of a series of panels, pressed of steel sheets and shaped to form a compression member along the eaves, window

Fig. 6. Interior of Chesapeake & Ohio Mail Car.

openings, posts between and diagonal braces below, so that in connection with a light, continuous channel side sill from end to end of car as tension member, the side truss is complete, even before the side sheets and the lining are applied. This is another way to avoid excessive motion in the roof joints along the eaves and forms a deep, efficient truss. This car has twelve such panels on each side, measuring 61 ft. $4\frac{1}{2}$ in. (18.71 m.) over corner posts, but any number can be used, to suit the length of the car desired. Trucks and the roof con-

struction will admit electrical equipment. For further details see Ry. Age Gaz., June 11, 1915.

During the past year the Union Pacific has added a large number of steel passenger-train cars to its equipment. They were of the arch-roof type, practically of steel throughout, except the diners and the Baggage Buffet cars, which had wood lining. Otherwise, the designs were substantially alike, consisting of I-beams for centre sills, angles for floor supports, side sills, belt rails, eave members, posts, and using rolled channels for carlines. These cars are insulated with three-ply hair felt and the floor is built up of three layers of various compositions, with galvanized iron at the bottom. The head lining is agasote. See Fig. 8.

On Dec. 31, 1914, according to a statement of the Special Committee on Relations of Railway Operation to Legislation, there were in service in the United States alone 12,900 steel, 5700 steel underframe and 43,512 wooden passenger-train cars.

FLAT CARS.

The accompanying Figs. 9 and 10 illustrate the typical flat car of today. All the sills are of the fish-belly type, pressed and reinforced at top and bottom to suit the strength required. If less capacity is wanted, the side sills are sometimes made straight, preferably of rolled channels. At times the sills, instead of being pressed, are built up of plates and angles. We now have cars of 40, 80 and even 100 tons capacity. This means that such a load is carried only if somewhat distributed on the car; if concentrated at the centre, two thirds of these loads only are allowed.

On this kind of car a cross sectional area of 24 sq. in. (154.83 sq. cm.) is recommended, regardless of capacity, so as to take care of end shocks properly. The centre sills are now preferably made to pass beyond the body bolsters, and in the majority of cases, these sills extend from end to end of car. This means an interrupted body bolster built in between the sills.

A 100-ton capacity flat car for the Pittsburgh & Lake Erie R. R. Co. has been described in the Am. Engr. & R. R. Jour., March 1912.

Fig. 7. Pullman Steel Sleeping Car.

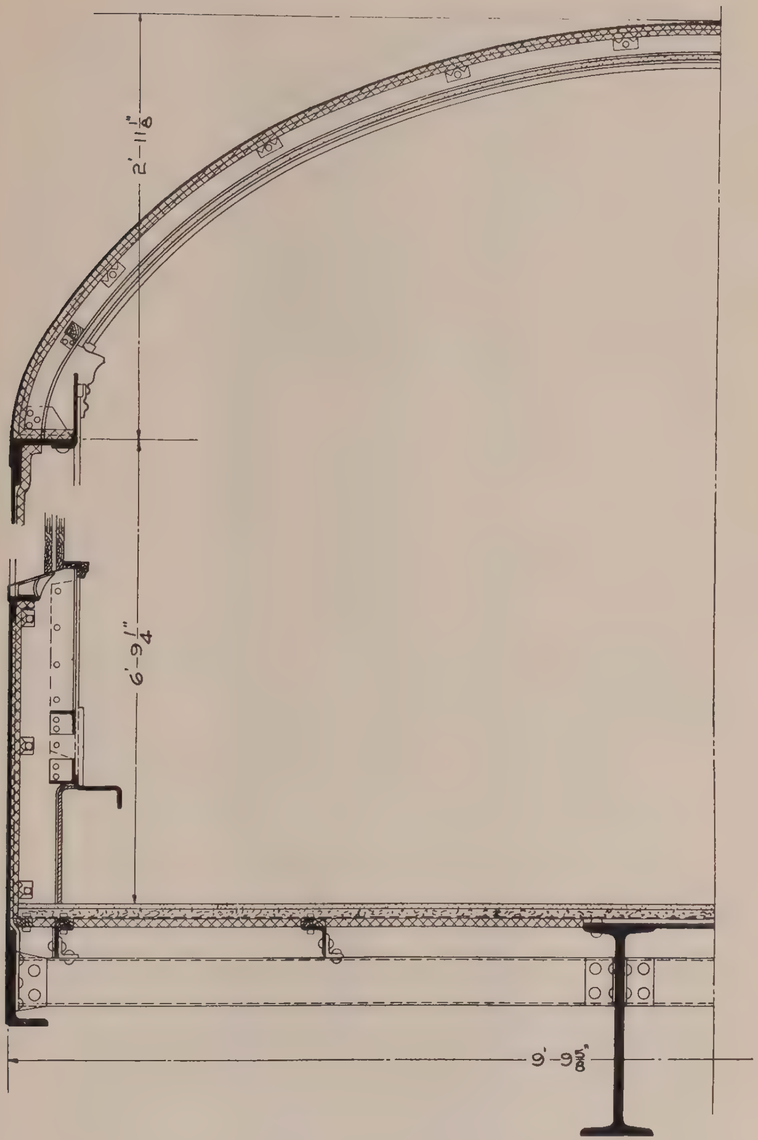

Fig. 8. Cross Section of Union Pacific Steel Passenger Car.

Fig. 9. Flat Car.

GONDOLA CARS.

The all-wood gondola cars are disappearing fast and steel is now used more and more. In certain cases, however, wood floors and sides are very useful, and for this reason many composite cars will always be found in our trains, and year by year new ones are being built.

The Pennsylvania Railroad Company's Class GR car, Fig. 11, is possibly the most typical example of this kind. It is of 50 tons capacity, has all four sills fish-bellied, pressed, sometimes built up, and properly reinforced at top and bottom; and since the same rules govern in regard to loading as on flat cars,

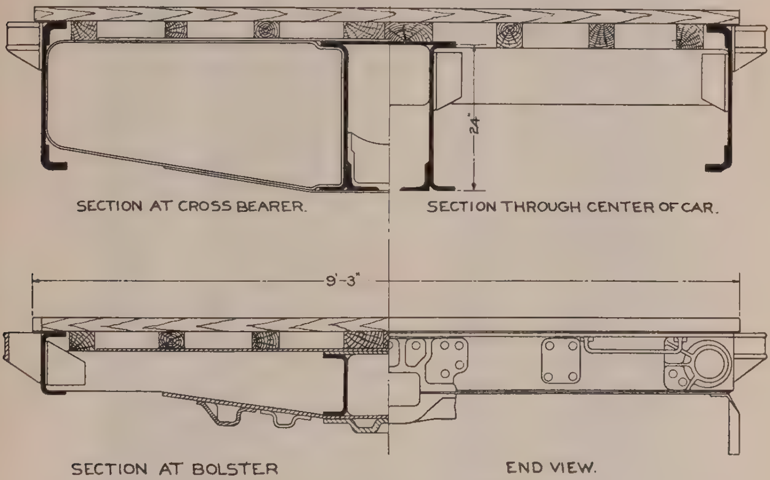

Fig. 10. Cross Section of Flat Car.

only two thirds of the capacity is carried when concentrated near the centre. The ends are made to drop, accommodating long material.

Quite often composite cars are made with steel side frames by simply adding top angles and diagonal braces. In this way we get an effective truss to carry the load, so that the centre sills can be straight members. See Am. Engr. & R. R. Jour., May 1907.

When built of steel the car as shown in Fig. 12 no doubt represents the average gondola of this country. It is the Pennsylvania Railroad Company's Class GS car. The centre

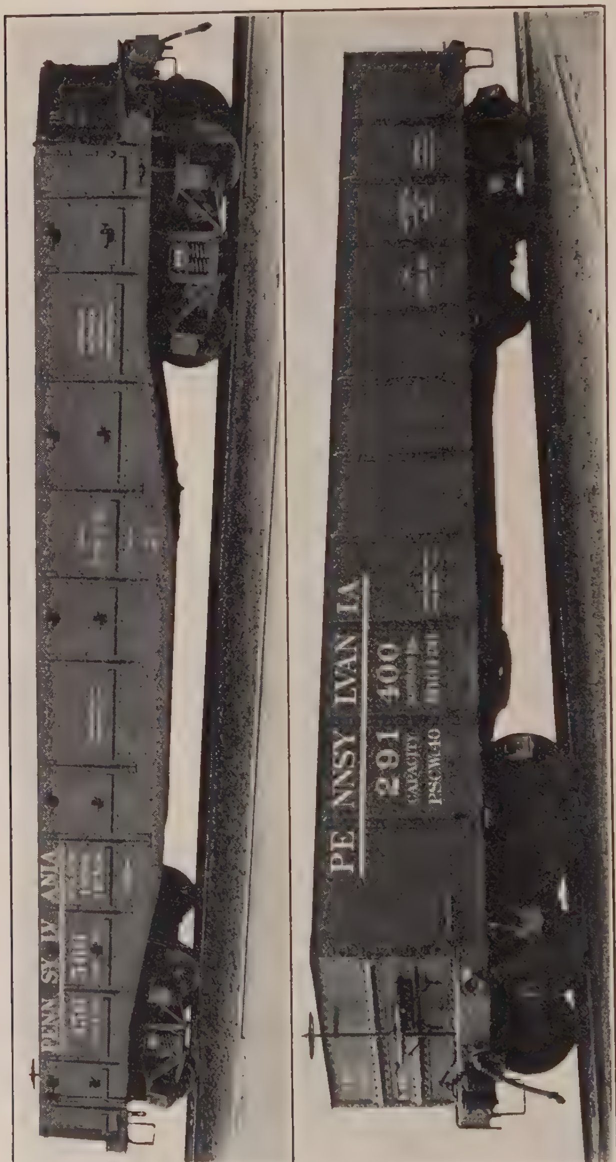

Fig. 11 (Upper). Composite Gondola Car.
Fig. 12 (Lower). 50-Ton All-Steel Gondola Car.

sills are of fish-belly shape of moderate depth, inasmuch as the sides are constructed as girders which will carry the load. It is, of course, important to connect the stakes well at the deep cross bearers so as to keep the sides in line and to retain their maximum carrying strength.

The car in question is sometimes equipped with small hoppers and drop doors, sometimes with drop ends, sometimes with both. Many railroads, however, prefer the drop doors flush, so as to have a perfectly flat floor when the doors are closed.

In Fig. 13 a 90-ton gondola is shown which is equipped with six-wheel trucks.

A very useful modification in the gondola car is the feature of dropping the whole floor either from end to end or between the trucks, getting a self-clearing side-dump car, besides having a flat-bottom gondola car when the floor is up. On account of these various features this type is commonly known as general-service car.

In Fig. 14 the doors are raised by chains and locked by letting the operating shaft creep under the end of the doors, so as to relieve the operating device of undue strains under the load.

Fig. 15 shows a general-service car where the doors are raised and locked by an offset operating shaft.

HOPPER CARS.

By far the most effective car for handling coal and bulky freight is shown in Fig. 16, known as a hopper car. This form is practically standard on every coal road. It will be noticed that the doors open away from the lading instead of sliding along the same, which was found troublesome in freezing weather. This car is self clearing. The centre sills do not carry much of the load; their main function is to take the end shock. The body of the car is well braced in the centre, inasmuch as the cross hood extends from side to side and forms a rigid backbone for the car in all directions. The sides are deep, hence, form efficient members for carrying the load; and in order to keep them straight and vertical, a substantial angle bar along the top edge has been found essential.

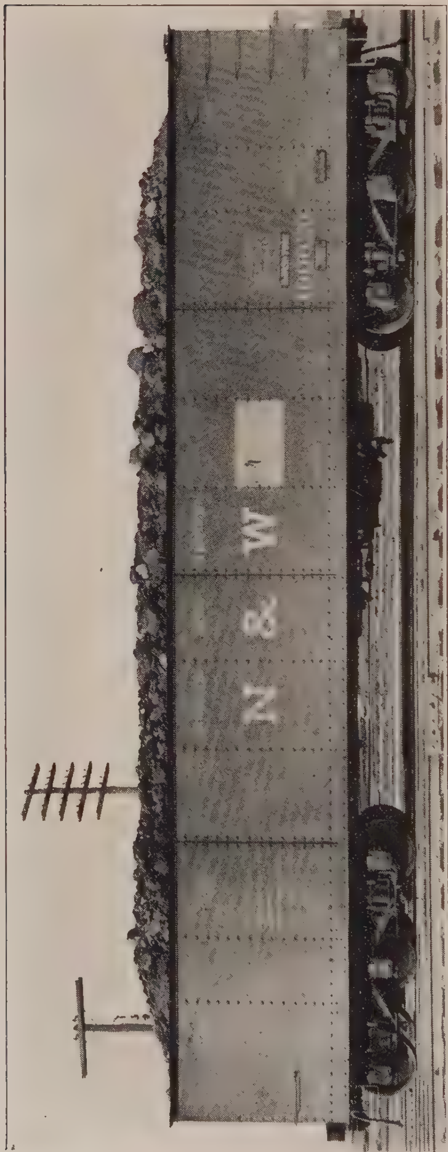

Fig. 13. 90-Ton All-Steel Gondola.

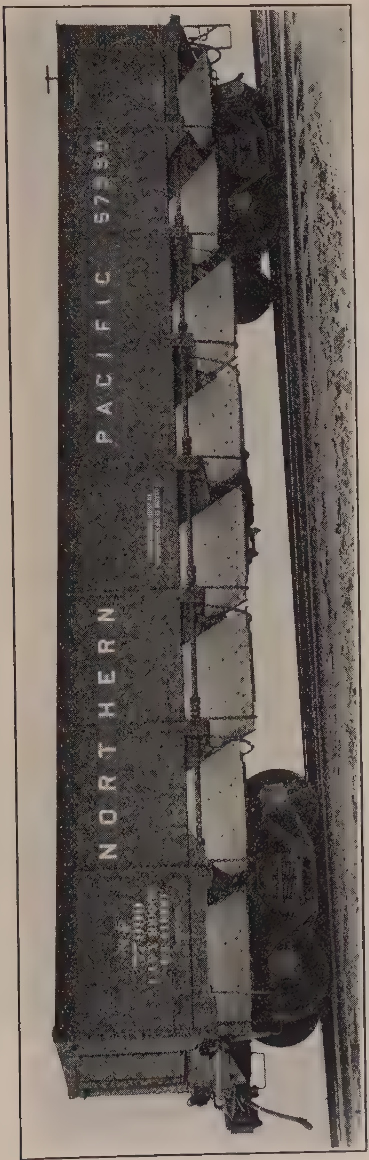

Fig. 14. General Service Car with Creeping Operating Shaft.

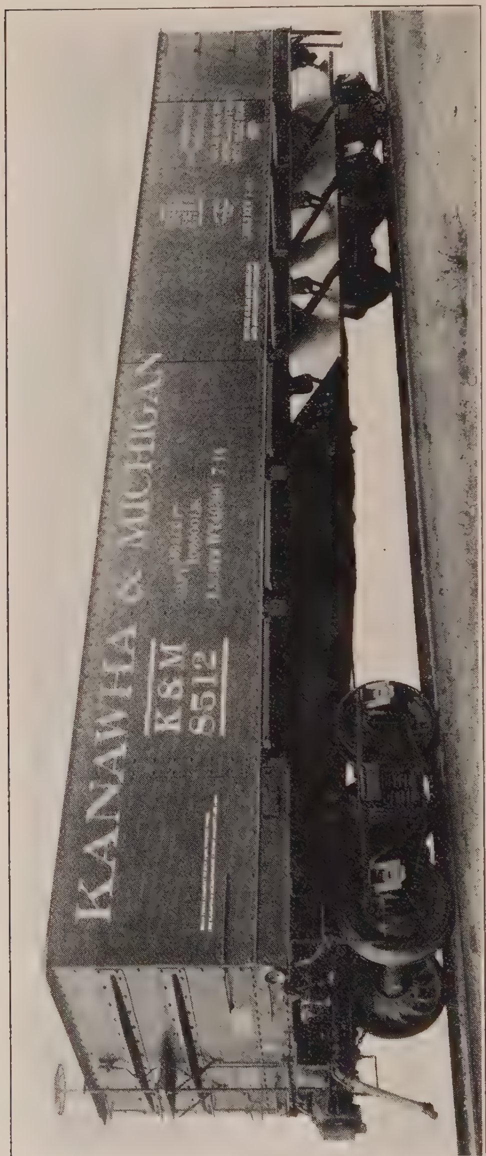

Fig. 15. General Service Car with Offset Operating Shaft.

In several cases the hoppers have been turned around so as to swing the doors from side or centre sills. This led to various designs of ballast, coke and dumping cars. A very useful dump car on this order has been used to good advantage by the Union Railroad in handling cinders and furnace refuse material. The car has two long doors, each one of which is held up at each corner by a chain support. When the load is to be dumped between the tracks, the central edges are dropped by a winding shaft arrangement, and if the load is wanted outside of the tracks, the outside chain supports are dropped. The car empties the load quickly and completely, which accounts for the great savings made in handling such material. See Am. Engr. & R. R. Jour., February 1909.

COKE CARS.

The same longitudinal arrangement of the doors led to a coke car shown in the Railroad Gazette of July 17, 1903. Here the doors, instead of dropping, swing out from the side, and the car was so arranged that in order to obtain the full 50-ton capacity with coke, the car was heaped, but whenever used for coal, was only loaded to the top of specially located cross ties.

The car now often used in carrying coke is a long, deep hopper car with four separate hoppers provided with horizontal drop doors, which leave, when dropped, a series of unobstructed downward openings. This car is illustrated in Fig. 16A.

Since the sides are made very deep to hold the load, the upper part of them is sometimes made of netting or expanded metal, so as to keep the dead weight down without impairing strength. See American Engineer and Railroad Journal, August 1907.

BOX CARS.

When the Baltimore & Ohio Railroad in 1862 built a number of all-steel box cars with wooden underframes, our older railroad friends hardly dreamed that these small and not altogether successful vehicles would be the pioneers in an industry of such tremendous magnitude.

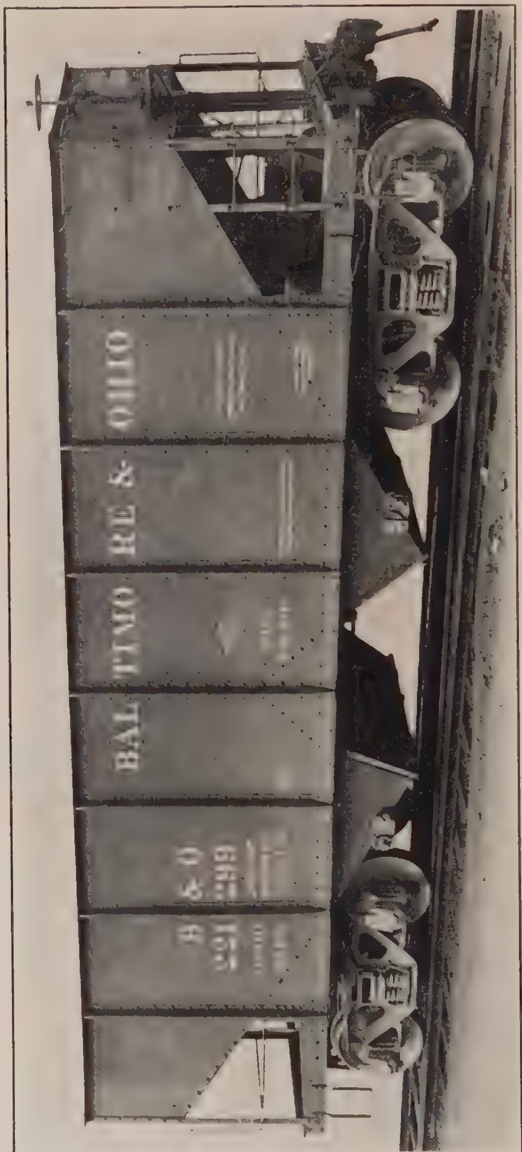

Fig. 16. 50-Ton Hopper Car.

Fig. 16A. Coke Car.

Fig. 17. Steel Underframe Box Car.

From that date on, for over thirty years, wood was entirely used on our equipment—still the capacity of cars was steadily increased, the trains got longer and the end shocks more destructive, so that the wooden sills could not stand up in service any longer. This brought about steel underframes.

Here, as a rule, fish-bellied centre sills were used to carry part of the load and to resist the end shocks, while the side sills consisted of angles or Z-bars. The body bolsters were usually built in between the sills, and a great many of this type of car were built from 1900 on.

This car, besides forming a stepping stone to an all-steel box car, also forms an economical means of strengthening and using up thousands of existing all-wood box cars. A fair example of this kind of car is shown in Fig. 17.

Further efforts along this line have brought about spasmodic cases where the body, or the frame at least, was made of steel, in order to assist the underframe in carrying the load.

Already in November 1900 the Santa Fe Railroad had three all-steel box cars built. The underframe consisted of six 10-in. (25.4 cm.) channels; the sides were of flanged-steel panels; the floor, the door and lining were of wood, and the carlines and the roof were of steel. See Ry. & Engng. Rev., May 4, 1901.

The Railroad Gazette of June 14, 1901, published a design of box car where the framing was of pressed steel, designed to carry load. The sheathing was left off and double wooden lining used instead. The floor was made of wood but the underframe and roof were of steel.

The Norfolk & Western in 1902 built a box car with a steel underframe, steel posts and braces, but wooden sheathing and wooden lining. (See Railroad Gazette April 18, 1902.) A car of this type is shown in Fig. 18. Besides having a steel frame, it is also ventilated for the transportation of fruit and other perishable freight.

Since 1908 the Union Railroad and the Bessemer & Lake Erie have made experiments with an all-steel car with steel floor, doors and roof and without any lining. This car was used in various ways, and, contrary to expectations, no damage resulted from sweating of the steel or other climatic condi-

Fig. 18. Ventilated Steel Frame Box Car.

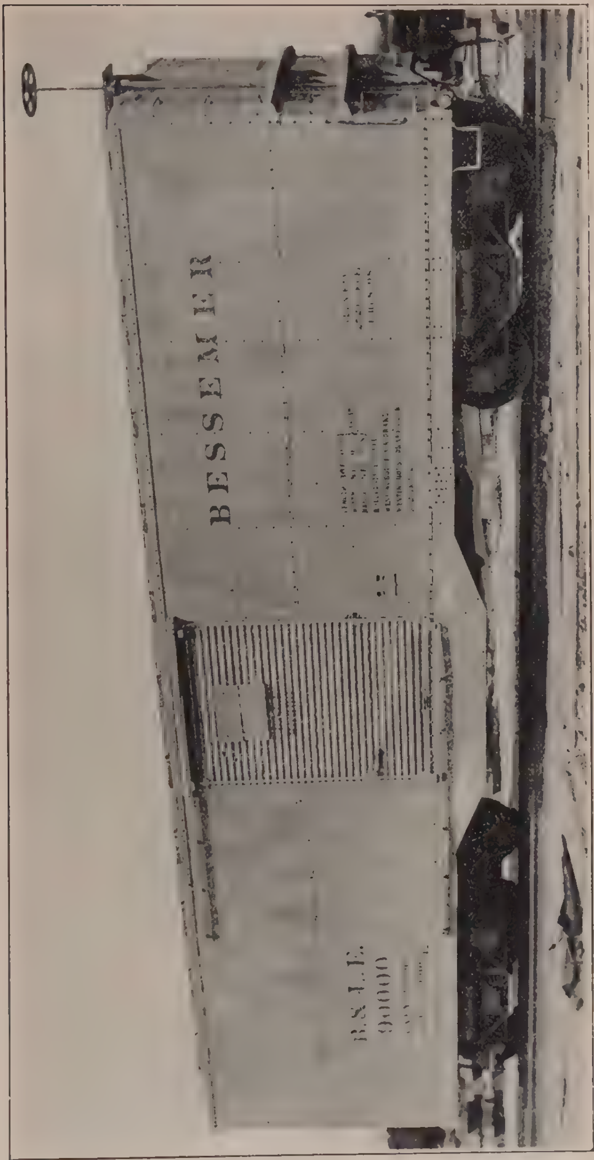

Fig. 19. All-Steel Box Car with Steel Floor and without Lining.

Fig. 20. Pressed Steel Frame Box Car.

tions. The car is shown in Fig. 19 and in the Railway Age Gazette, March 22, 1912. After a six-years' trial the Bessemer and Lake Erie Railroad Company ordered one hundred of such cars. It may be mentioned that this is the same railroad that ordered the first lot of one thousand steel hopper cars in 1897.

In the beginning of 1907 the Union Pacific built two sample all-steel box cars with the sheathing left off and the lining, frame, roof, floor and doors made of steel, and in the early part of 1910 another similar sample car was built. These three cars had centre sills formed of a single I-beam projecting

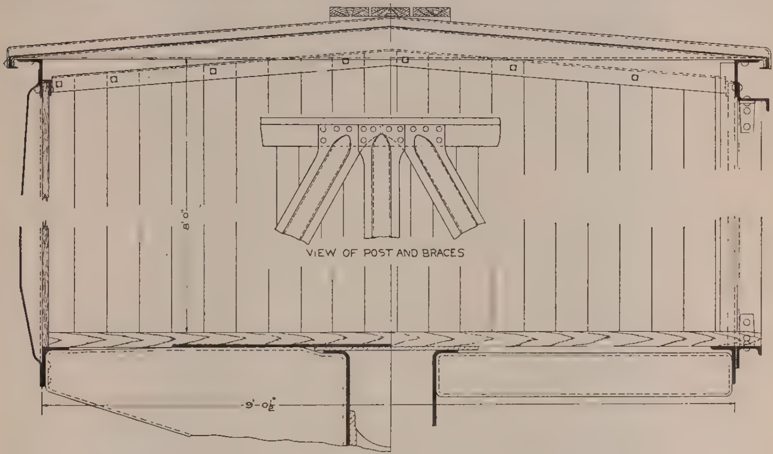

Fig. 21. Cross Section of Pressed Steel Frame Box Car.

through the body bolsters, and the draft sills were offset and attached to the projecting part of the I-beam centre sills. See Railway Age Gazette, Feb. 11, 1910.

After many such spasmodic trials and experiments the Pennsylvania Railroad Company designed and built a lot of cars which up to this time have been their standard car. (See Figs. 20 and 21). It is of the steel-frame type with wooden floor and lining and no sheathing. The centre sills are of the fish-belly construction, reinforced on top and bottom, and two deep cross bearers divide the whole construction into actually three equal parts. These cross bearers, in conjunction with the end sills, transmit the load from the side sills to the centre

Fig. 22. Pressed Steel Frame Automobile Car.

Fig. 23. Structural Steel Frame Box Car.

Fig. 24. All-Steel Car with Wooden Floor and Lining.

sills at the points where the bending moment is a minimum, and from there on it is transmitted to the centre plates by the centre sills themselves. In other words, the same principle has been followed as on their passenger car constructions.

The side sills are rolled angles and the posts and braces are of U section, made of pressed steel, which in combination with the side sill and the eave angle forms a light but effective truss.

The roof is of steel, supported by trough-shaped, pressed-steel carlines. At the eaves provision has been made for ventilation, without, however, allowing the rain and snow to enter. The doors are also made of steel. This same construction is

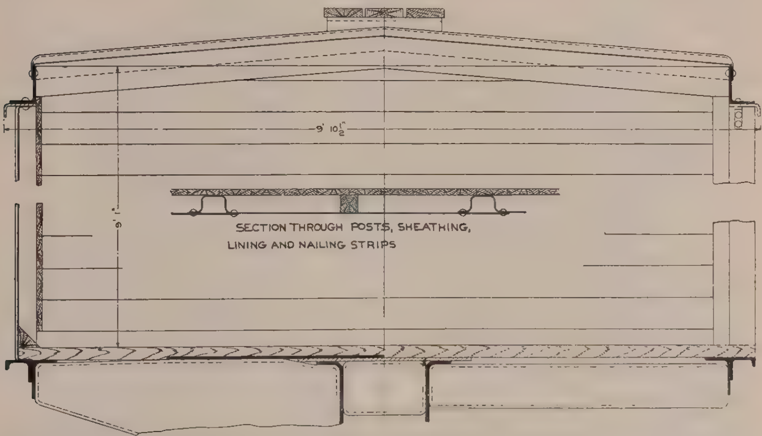

Fig. 25. Cross Section of All-Steel Box Car with Wooden Floor and Lining.

likewise used for stock, automobile and refrigerator cars with comparatively few modifications.

The stock cars use slats instead of a solid lining. The automobile cars have wide double sliding doors at the side of the car, and one end is made of swinging doors, as is clearly shown in Fig. 22. The roof construction at the eaves is also slightly different from that on the box car.

The refrigerator cars naturally vary as to size of doors and inside insulation.

A similar car is shown in Fig. 23. However, rolled steel is used instead of pressed steel. The side and centre sills consist of channels 8 and 15 inches (20.32 and 38.1 cm.) respect-

ively. Posts, braces and eave members are of Z-bar section. The Canadian Pacific and the Grand Trunk Railroads use this form of box car very extensively.

Figs. 24 and 25 represent the Pennsylvania Railroad Company's latest design of box car—their class X-25. It is similar to the steel-frame car above described, but is provided with a steel sheathing. This will give the car a plain appearance from the outside and will make it absolutely weatherproof.

The sheathing consists of ten steel panels per side of car, each one being provided with a flange at the top and the bot-

Fig. 26. Ore Car.

tom, which flanges in turn are rivetted to the side sill and the eave angle. Each panel has one side edge pressed up to form a post, while the other side is flat. This post extends inwardly and the flat edge of the adjoining sheet is made to cover the indentation. The diagonal members have been left off, as the steel sheets themselves will act as braces.

ORE CARS.

The ore trade in this country is fast increasing in importance, and to handle this commodity efficiently and quickly has

been for years the aim of those engaged in this business. This led to a constant improvement in the ore car.

Figs. 26 and 27 show a car where the floor is formed of two large longitudinal doors meeting in the centre. The side sills are made to take the end shocks and the centre sills are left

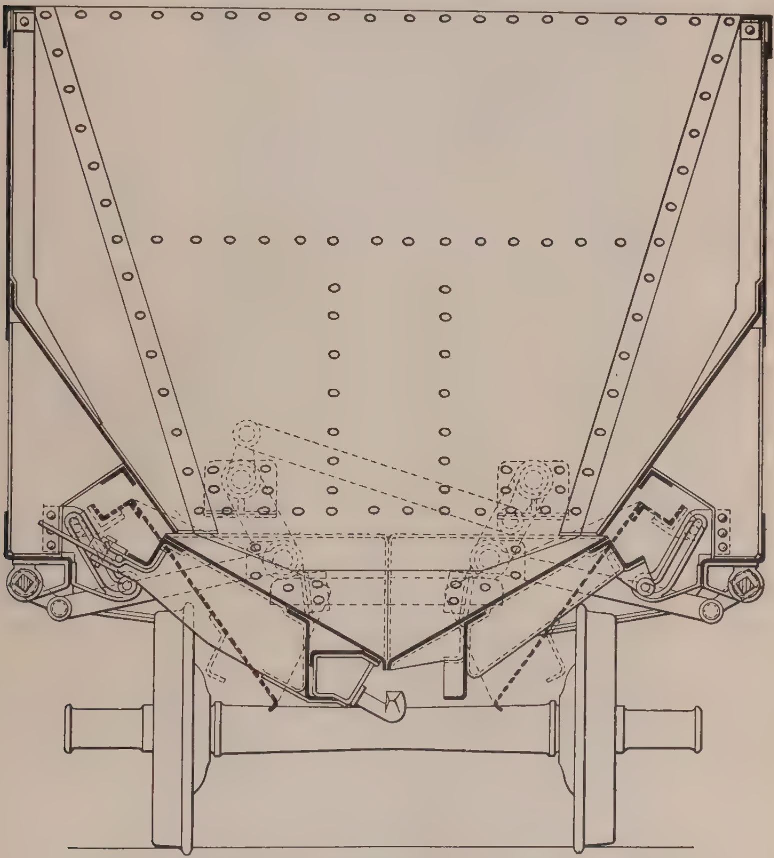

Fig. 27. Cross Section of Ore Car.

off. The doors are closed by swinging them on sliding pivots by means of operating shafts and levers. In this way the height of doors is the same whether closed or open. They are locked by separately operated spring hooks, which grip the inside edges and hold them tight together until the hooks are tripped. All angles of the sides and ends are very steep, and

when the doors are open, nothing remains to prevent an almost instantaneous discharge.

There are other similar designs of ore cars used with equally astonishing results. This undoubtedly is due to the fact that the essential underlying conditions are the same in every case, namely, steep angles of the sides and ends and large, quick-opening doors, with no obstruction whatsoever left. The operating mechanism does, however, differ greatly.

TANK CARS.

The tank car shown in Fig. 28 is a fair representation of this kind of equipment. The car body consists principally of the centre sills and bolsters, and the side sills and the floors are usually left off. The standard minimum cross-sectional area of the centre sills is 30 sq. in. (193.5 sq. cm.), so as to stand the end shocks safely. The sills themselves are not designed to carry any load. The tanks are self-sustaining and rest on the bolsters. The fastening between the tank and frame is preferably made midway between the trucks by rivetting or keying, which will give the tanks a chance to expand or contract independently of the car frame. This is the more important since some heavy oils at times have to be heated to make them flow. A great deal of attention has been given this matter by the railroads through their M. C. B. Association and no expense was considered too great to make this line of transportation absolutely safe.

For this reason, that Association adopted standard tank-car specifications, which rigidly define the tank, their fixtures and also the most important details of the car itself.

TRUCKS.

Fig. 29 shows the well-known Pullman truck made in cast steel. This truck has been used for decades past and this fact alone will prove its merit.

One of the main features of the Pennsylvania all-steel passenger cars is a low centre sill, so as to get the centre of the draft-gear well within the cross section of said sills. For this reason another design of truck was necessary. Fig. 30 shows a four-wheel construction, which was designed for the

Fig. 28. Tank Car.

lighter passenger-train equipment. Another decided constructive feature is the fact that the wheel pieces, in addition to the previous functions, also take the place of the equalizers. This is accomplished by locating the helical springs on top of the journal boxes. Here valuable space in a vertical direction was gained by making the wheel pieces of two channels with

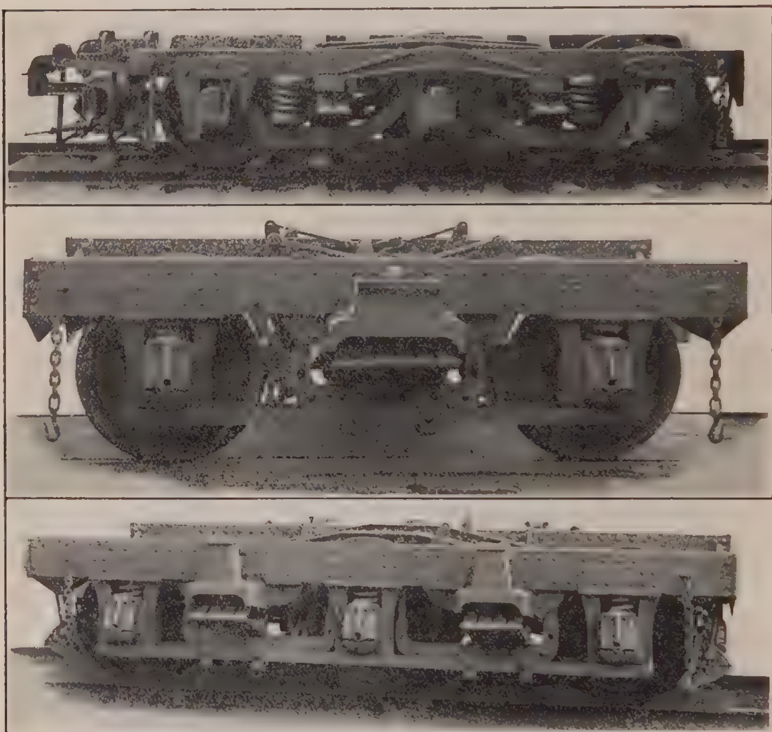

Fig. 29 (Upper). Pullman Truck.
Fig. 30 (Center). Pennsylvania Four-Wheel Truck.
Fig. 31 (Lower). Pennsylvania Six-Wheel Passenger Truck.

flanges turned inside, but spaced far enough apart to let the springs extend between their webs.

For all its heavier all-steel passenger-train cars the Pennsylvania Railroad Company has designed a six-wheel truck on the same principles as its four-wheel truck. Here the centre plate is directly above the centre axle, and owing

to the small clearances vertically, the cross girders which connect the two truck bolsters had to be spread sufficiently, so as to let them extend upwardly without interfering with the centre sills. Fig. 31 shows this truck quite clearly.

The trucks for freight cars, aside from some experimental cases, have not been changed a great deal. The well-known arch-bar truck still holds its own. It is true, cast steel in various forms has been used to replace the rolled arch bars. This naturally reduces the number of detail pieces. One type

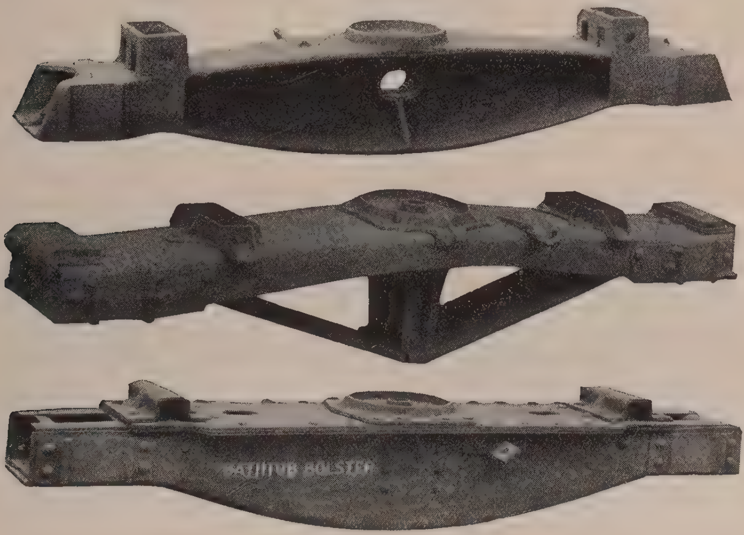

Fig. 32 (Upper). Cast-Steel Truck Bolster.
Fig. 33 (Center). Trussed Truck Bolster.
Fig. 34 (Lower). Pressed-Steel Truck Bolster.

of such cast steel designs combines the two rolled arch bars and still uses the bottom tie bar and the standard journal boxes. Another type goes further by doing away with the tie bar and journal-box bolts, using pedestals instead. In this case the M. C. B. standard boxes cannot be used. Still another type of cast-steel design combines the journal boxes and the truck side-frame into one single casting.

The bolsters in all these variations of the arch-bar truck are made either of cast steel, rolled or pressed material.

Fig. 32 shows a typical design made of a steel casting. It, as a rule, is strong and stiff. The design shown is of an I cross section, but in a great many cases it is made of a box section.

Fig. 33 shows a trussed bolster. It is very strong and slightly resilient.

Fig. 34 represents a pressed-steel type of truck bolster. This form is very reliable, strong and stiff.

The phenomenal increase in the capacity of freight cars has induced the Norfolk & Western Railroad Company to design and use a six-wheel freight truck, a photograph of which is shown in Fig. 35. Here a four-pronged solid spider casting transmits the load from the centre plate to all four groups of

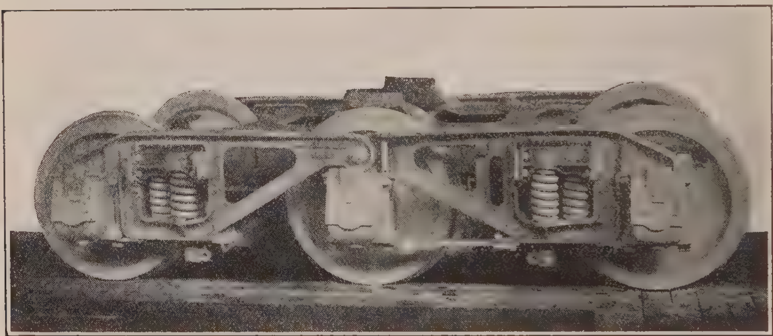

Fig. 35. Six-Wheel Freight Truck.

springs. These springs in turn rest on the truck sides. Possibly the greatest novelty of this truck is the fact that these truck sides are also acting as equalizers. Each pair of them is kept from spreading and from closing in by the just mentioned spider casting. These trucks are used in connection with the 90-ton Gondola car shown on a previous page.

In coming to a close, it may be stated that the tremendous progress made in all these car constructions during the last ten years must certainly be acknowledged. Great sums of money have been spent in doing so. Aside from this the public will appreciate, especially, that part of this expense went into passenger equipment for the safety and the comfort of the traveling public without the companies obtaining therefrom any direct revenue.

The author wishes to extend thanks to the car companies and the railroads, who so kindly furnished him some photographs, and especially to the Pressed Steel Car Company for the many blue prints put at his disposal.

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DISCUSSION

Mr. Passeck. **Mr. C. T. Passeck*** said that the present tendency was not to exceed 40 to 50 tons capacity in the design of box cars; this limit is set by the cubical capacity of the car. The movement in the future will be toward steel cars. Some roads have trouble with the sweating of steel cars. In the design of steel passenger cars the Southern Pacific Company had used separate panels which could be easily replaced. In future, agasote or some other composition will replace steel in part. This material requires repainting about one-third as often as steel.

Mr. Baker. **Mr. C. W. Baker,**** Mem. Am. Soc. M. E., said that the new Erie steel car weighed a little less than the wooden car which it replaced. The aim

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** Editor in Chief, Engineering News, New York, N. Y.

now is to make a light car, as well as one that is strong and of large capacity. There is a very heavy dead weight now in passenger cars. Mr. Baker.

He stated that the electric railway people are reducing the weight of their cars. Every pound of weight saved, saves perhaps 50 cents in operating cost during the life of the car. Perhaps the weight may be cut down by using special steel, as has been done in automobile construction.

Mr. A. H. Babcock,*** Mem. A. I. E. E., said that some years ago some tank cars were designed with the bottom section of the tank heavy enough to replace the center sills and asked if this design still persisted. Also if the cast-steel truck frame for motor trucks for electric operation was of sufficient merit to persist. Mr. Babcock.

Referring to Mr. Baker's remarks, he said that the lightest car in passenger service in the East weighs 1250 lb. per passenger, and some weigh 1400 to 1500 lb. per passenger. The Southern Pacific steel suburban car weighs 761 lb. per passenger, seats 116 persons and has a length of 72 ft. 4½ in.

Mr. F. T. Oakley,* M. Am. Soc. C. E., asked as to the merits of the all-cast-steel truck as compared with the built-up truck. In a recent wreck he had seen a number of Pullman trucks badly damaged, but the trucks under the dining car, which were of the type shown in Fig. 31, were not much damaged. The built-up truck may be better. Mr. Oakley.

Mr. Arnold Stucki said that Mr. Passeck was right about the 40- and 50-ton box car; that we cannot well get more than 50 tons into a box car. Mr. Stucki.

We are now building 100-ton capacity flat cars and hopper cars. The 70-ton hopper car is now standard. A further increase may be looked for because the principle is right. The sweating of steel cars is possibly a result of climatic condition, as Mr. Passeck has said. The Bessemer & Lake Erie and the Union, who built the cars with no lining, had no trouble, though they sent a car of cement from coast to coast. But one car does not establish a fact.

With regard to tank cars: In some cases the center sills have been done away with entirely and the tank reinforced at the bottom. This involves a serious problem, however, as the tank is subjected to heavy blows, with consequent liability of breakage. A good many such cars are in service, but few, or none, are now being built. The best design is for the underframe to take the end shock and the tank to take the load. Connection is made at the center of the tank.

To Mr. Oakley's remarks he replied that he had seen cast-steel trucks and bolsters behave excellently in wrecks, and after having been straightened up, used again. Also, that he had seen some that showed clearly the treacherous nature of the material. If you have a well designed truck and a good casting everything will be all right. Rolled steel is all right in railroad construction wherever you put it. He could not say which is better; each had proved its case.

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Paper No. 92

THE FLOATING EQUIPMENT OF A RAILROAD.

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Railroads whose terminals are located in harbors of importance or whose rails touch such harbors require a considerable amount of floating equipment to complete their delivery agreements, and probably nowhere does this kind of equipment become so necessary as in the Port of New York, where all the railroads require vessels to complete their deliveries in whole or in part. The territory covered by this water-borne movement is shown on Plate No. 1, which is a map of Manhattan Island, showing the surrounding water area within the lighterage limits; and the extent of this territory gives an idea of the large amount of floating equipment required by the different roads reaching New York. Requiring as it does almost every type of equipment, a description of the floating equipment used in New York would seem to best describe the subject of this paper.

It has been the custom to look upon passenger traffic as the most important of a railroad's functions. A glance at Plate No. 1 will show that most of the roads have their rail terminals on the New Jersey shore of the Hudson River, the passengers reaching Manhattan Island by ferryboats. In fact, the first steam ferryboat was used on the Hudson River. Step by step this type of vessel has been improved to within a few years, halted now by the prospect that it will not be a very distant day before the various roads use tunnels under the Hudson River for their passenger train service.

The Hudson River ferryboat, aside from the feature of fire protection, is the highest development of the type. Plates 2A, 2B show in detail a design that is closely followed on all the modern boats, averaging 210 feet in length, with a displacement of 1,000 tons. The hull is built of steel, deck structure and guard beams of steel, but the superstructure is of wood. The main, or lower, deck is used jointly for passenger and vehicle traffic; the two gangways through the center have room for from eighteen to twenty vehicles; the passenger accommodations are along the sides. The upper deck is used exclusively for passengers, with elevated approaches thereto from the ferry station. The capacity of the vessel is about 2500 passengers, and eight minutes is the average time for the trip across the river. The vessels are propelled by two screws, one at each end, connected by a continuous shaft. The motive power is a vertical compound condensing engine of about 900 i.h.p., giving the vessel a speed of ten knots. The screw system of propulsion, which commenced to supersede the side-wheel system in 1891 and is now universal, while not as economical in fuel consumption, has many decided advantages: more space is available for passengers; better control is obtained in stopping and starting (a feature of much importance when so many "end on" dockings are made); and ability to proceed through the ice in winter without material interruption, which is a feature of much importance, affecting both the earning ability of the equipment and the convenience of the traffic. While the steam pressure carried on this type of vessel ranges around 160 pounds, no one particular type of boiler has been adopted. It would seem, however, that the water-tube type, affording, as it does, safety from disastrous explosion and being so flexible in operation that it will accommodate itself to the intermittent operation necessary, is the most desirable. The vessels have complete electric-light equipment in duplicate, generally indirect hot-air heating system, and complete pumping and fire-fighting facilities, particular attention being given to the feature of quick action with portable chemical extinguishers.

It will be noted that the above described type has a wooden superstructure. It is necessarily of light material and should a fire obtain much headway, it would no doubt be disastrous.

The fear of this prompted the construction of a ferryboat with a steel superstructure, in fact, of all steel construction, Plates 3A, 3B, 3C. Four of these are now in use on the Delaware River, and while none have been built for the Hudson River service, attention is called to what is a practical and desirable type of ferryboat that will undoubtedly be followed in localities where such service is developing instead of waning. The sketches show a ''single-deck'' boat, but the design contemplates an upper deck, should traffic require it. The motive power is similar to but less than that in use on the Hudson River ferryboats.

Originally, little attention was paid to the means of loading and unloading ferryboats, a platform hinged on the shore end with its outboard, or river end, resting on the boat being the means of providing for variation in tide level and consequent relative height of the vessel's deck. As the carrying capacity of vehicles increased, the length of the platform was increased to reduce the incline or grade; coincidently the weight of the platform or ''bridge'' increased, and means were then required to support, raise and lower the outboard end with more certainty; in some cases a pontoon supports the outboard end, supplemented by chain windlass to obtain exact control. A better plan is to raise and lower the bridge by electrically-operated screw gears, omitting the pontoon and counterweighting the dead load; but the growing use of the heavy automobile truck brought new problems in loading and unloading and it became desirable to not only control the height of the bridge, but also to provide some means that would keep the bridge and boat in constant vertical alignment and also relieve the boat of the weight of the bridge and the live load on it. Plate No. 4 shows a device now in use that not only accomplishes these requirements but also moors the vessel to the bridge automatically.

By far the most interesting operation of a railroad is the freight traffic, versatile, with ever occurring opportunities for improvement; and this condition obtains on floating equipment to a most marked degree. Only one trunk line has facilities for the delivery of freight by rail on Manhattan Island. It seems unnatural that such a condition should exist in the greatest ''freight consuming'' locality in our country; therefore, all

Plate 1. Manhattan Island and Surrounding Water Area within Lighterage Limits.

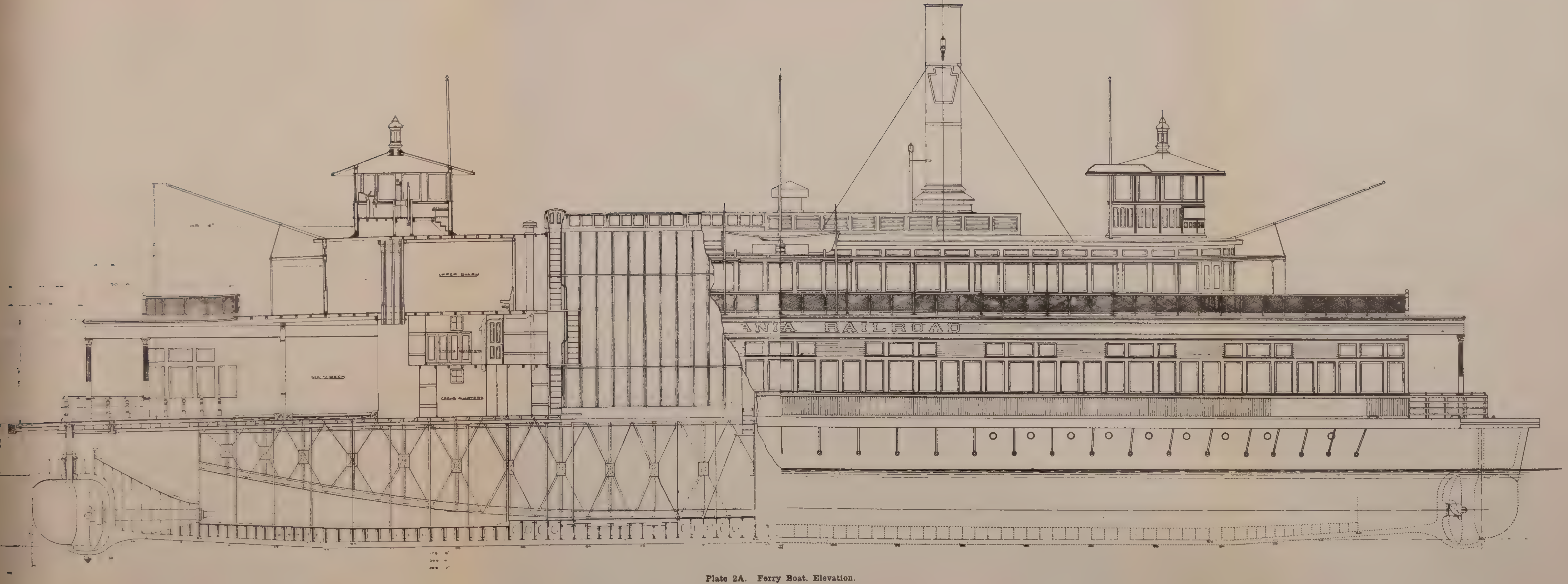


Plate 2A. Ferry Boat. Elevation.

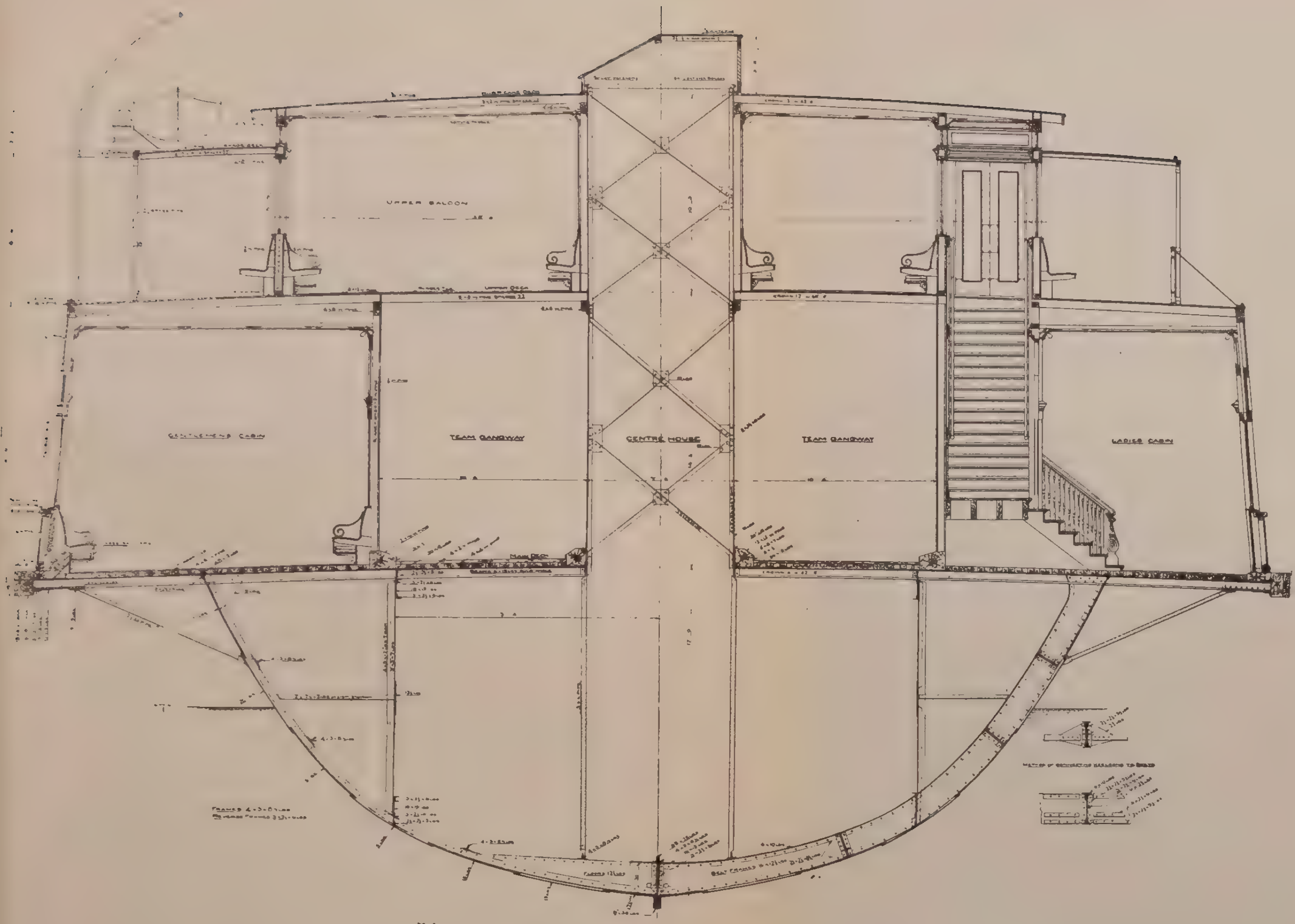


Plate 2B. Amidship Section, Ferryboat.

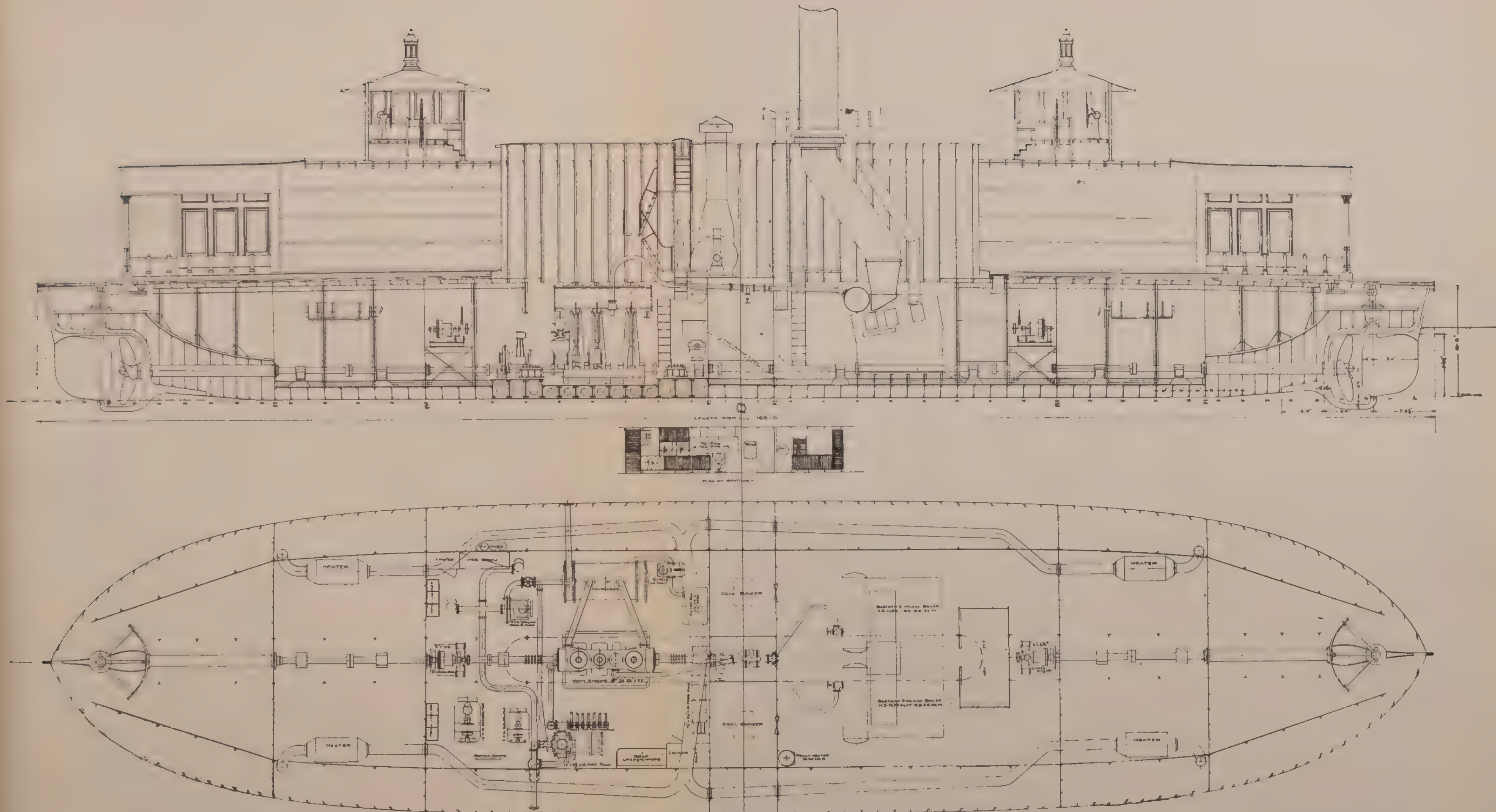


Plate 3A. Interior View of Fireproof Ferryboat.

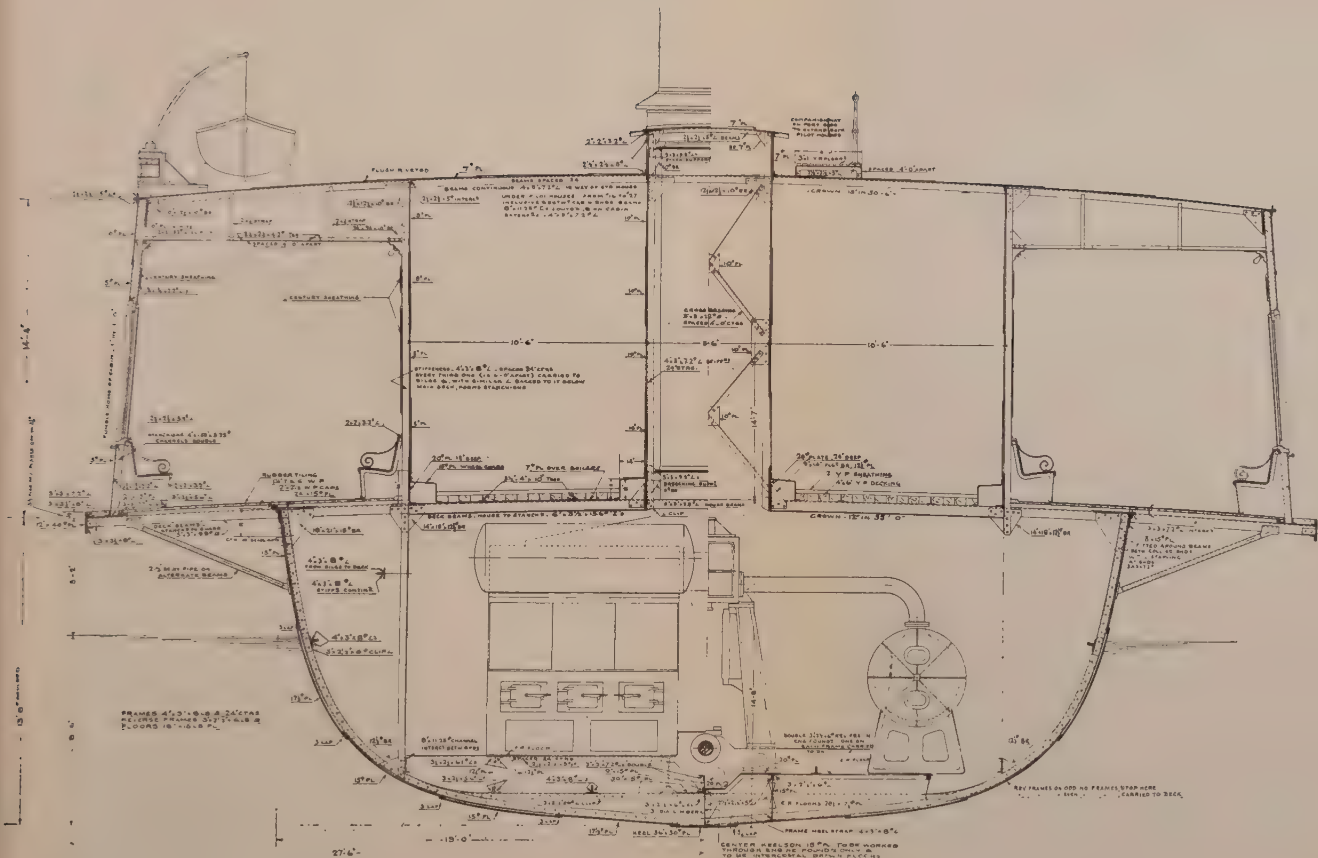


Plate 3B. Amidship Section, Fireproof Ferryboat.

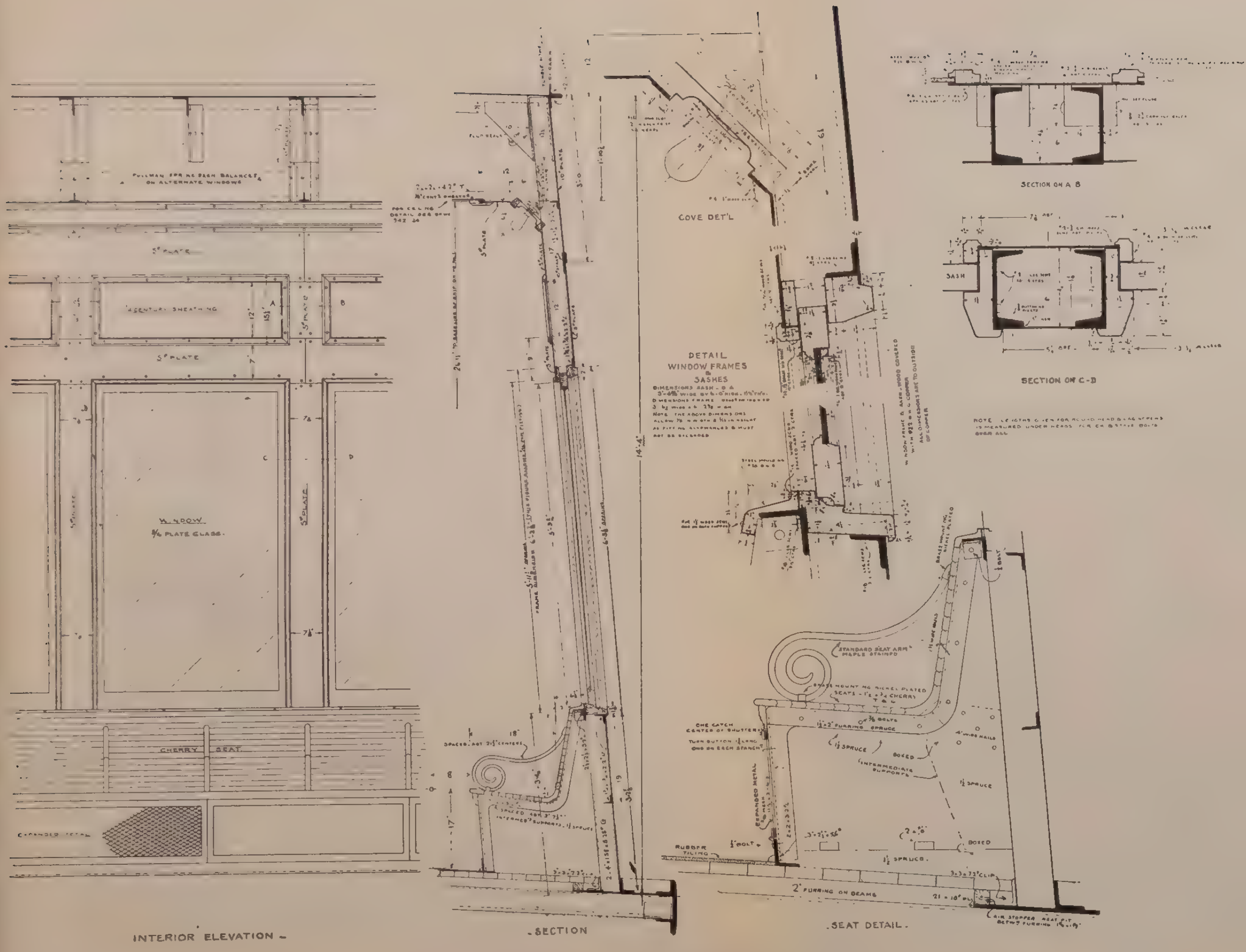


Plate 3C. Details of Construction, Fireproof Ferryboat.

the railroads must give much study to the problems occurring in transportation by water.

The different roads maintain their own freight stations on piers at various points on the water front of Manhattan. Cars are loaded onto "car floats" at the rail terminal and the floats are towed by "tugboats" to these piers; the cars are unloaded

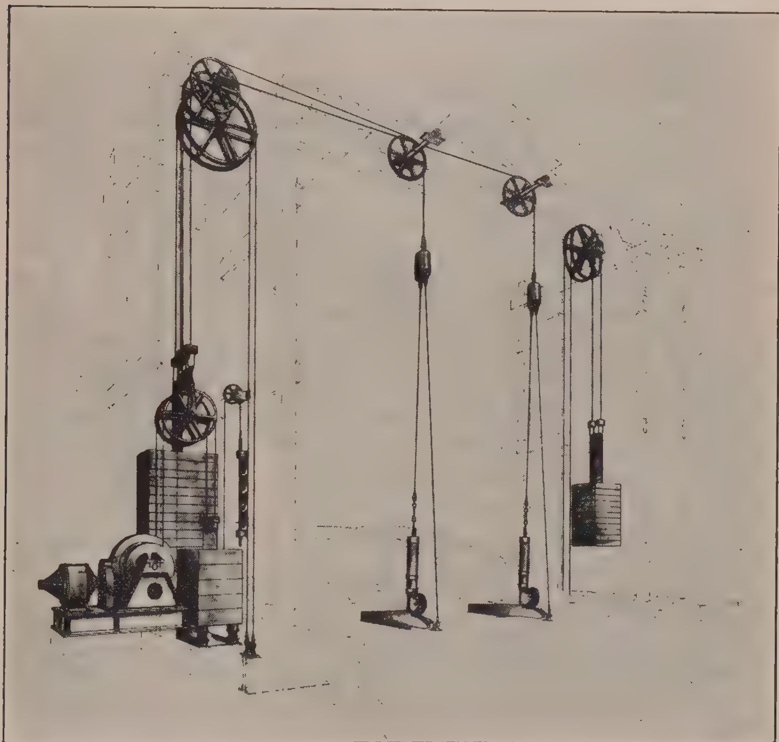


Plate 4. Device for Mooring Ferryboats and Counterbalancing Liveloads. Patented 1914.

there and reloaded while on the floats; all the freight handled at these stations arrives and departs on floats. Piers are usually long enough to berth three floats, and freight is taken from the car door, over gang planks, to the side of the pier by hand trucks, distributed around the piers, and stowed where it can be conveniently loaded on to a truck. In a few instances small

"yards" have been conceded, by the municipality, along the shore front and cars are moved from the floats into these yards by drill engines, permitting "tail board" deliveries, that is, from car door to truck or van; in still fewer instances large manufacturers adjacent to Manhattan maintain "float bridges" over which the cars can be moved direct to their warehouses; a traffic of considerable volume is also obtained in the interchange of cars between the different roads, principally between the trunk lines and their eastern connections.

The car floats used for this movement may be classed in two types; pier floats and transfer floats. Pier floats. as the name implies, are used to deliver freight to the freight stations on piers; the traffic is usually in less than car load lots (L. C. L. freight) and the loads carried are therefore less than those carried by transfer floats,—the cars on which are usually fully loaded at transfer stations before reaching the terminal,—or less than those containing heavier materials, such as coal, structural iron, etc. Pier floats are not required, therefore, to be as strongly constructed and are built of wood because of their lesser first cost and subsequent cost for maintenance. Moving them frequently and maneuvering around piers somewhat restricts their length. Plate 5 shows the usual type of pier float. It will be seen that they are of box form, sides nearly straight, with their ends slightly curved from keel to deck, so as to reduce somewhat the resistance in towing; they carry twelve cars, six on each side, and the roofed platform through the center is to permit the unloading of the freight in the offshore cars onto the pier against which the float is moored, or to a bulkhead against the end of which a float may be placed. The transfer floats, as before mentioned, must be more strongly constructed. They support three, and sometimes four, tracks, are longer than pier floats, and carry twenty-two fully-loaded cars. They are used principally for interchange between railroads and for the movement to the yards and manufacturing plants above mentioned. It has seemed impossible to construct of wood satisfactory floats of this type, and steel is therefore used. A typical float is shown on Plates 6A, 6B. As the pier and transfer traffic is not constant, or relatively so, it has been found desirable to maintain a type of float that could be used in either service, strong enough for the

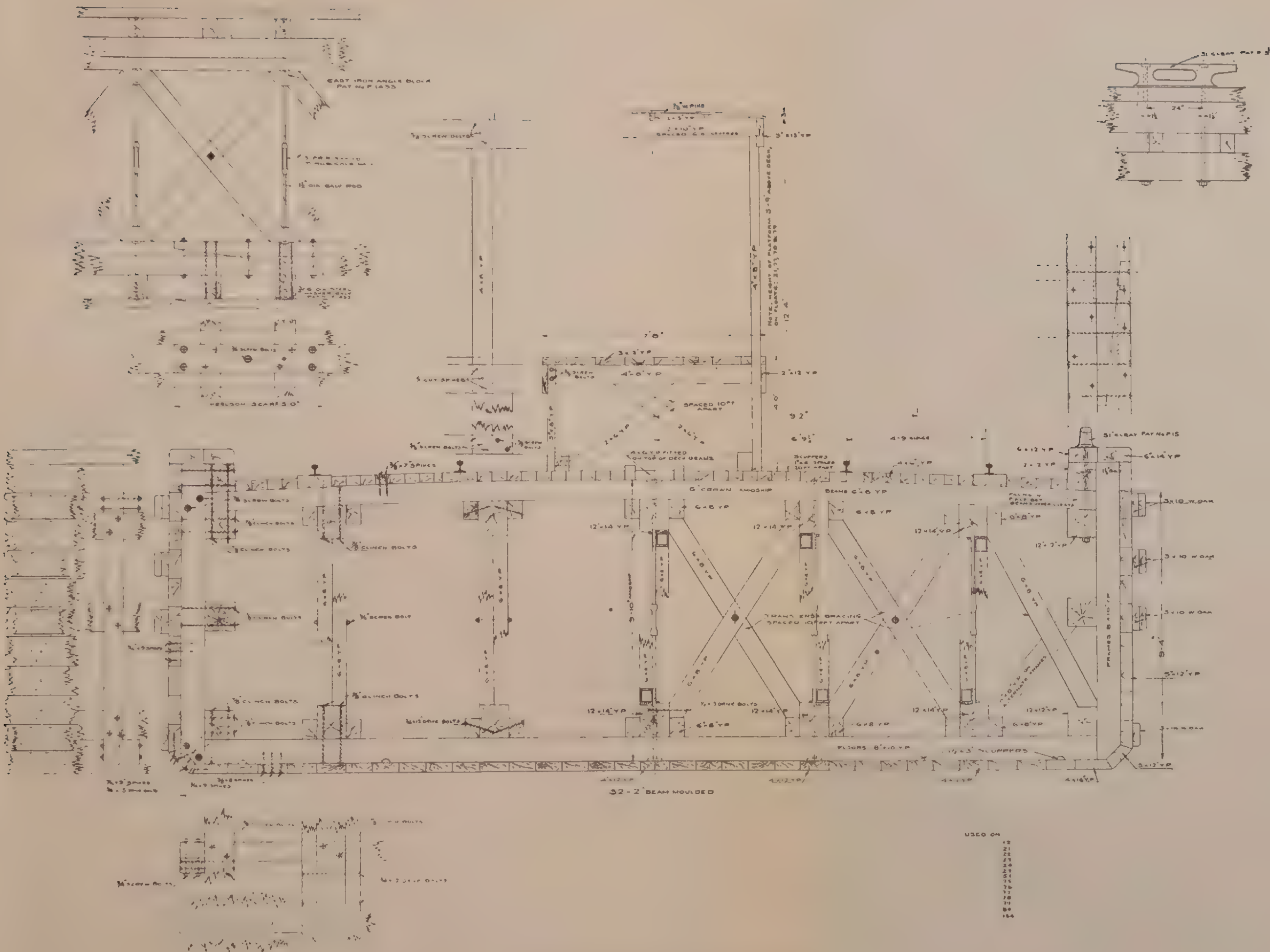


Plate 5. Amidship Section of Car Float, Pier Service.

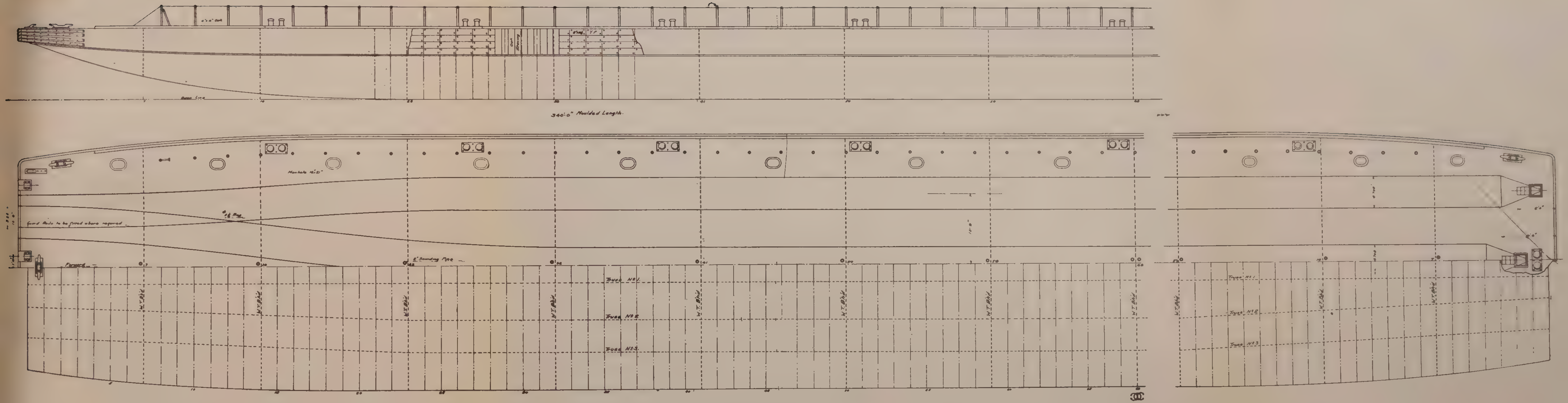


Plate 6A. Car Float, Transfer Service.

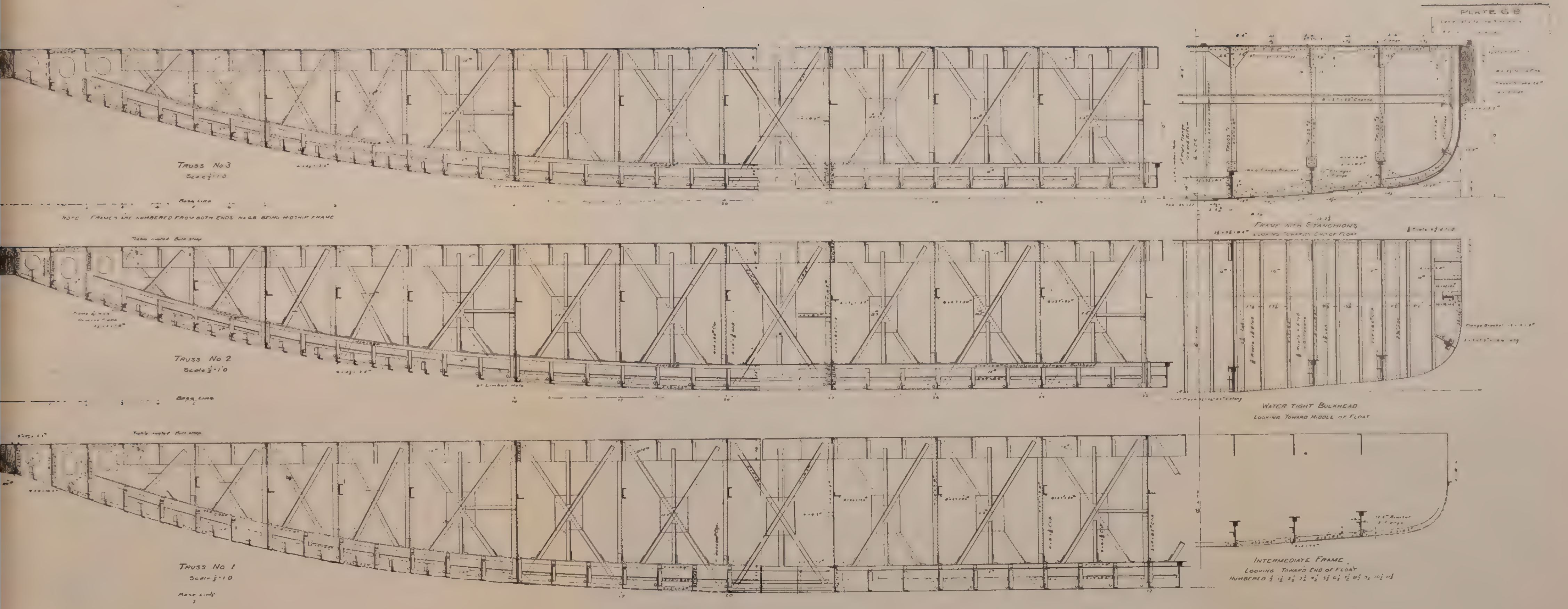


Plate 6B. Car Float, Transfer Service.

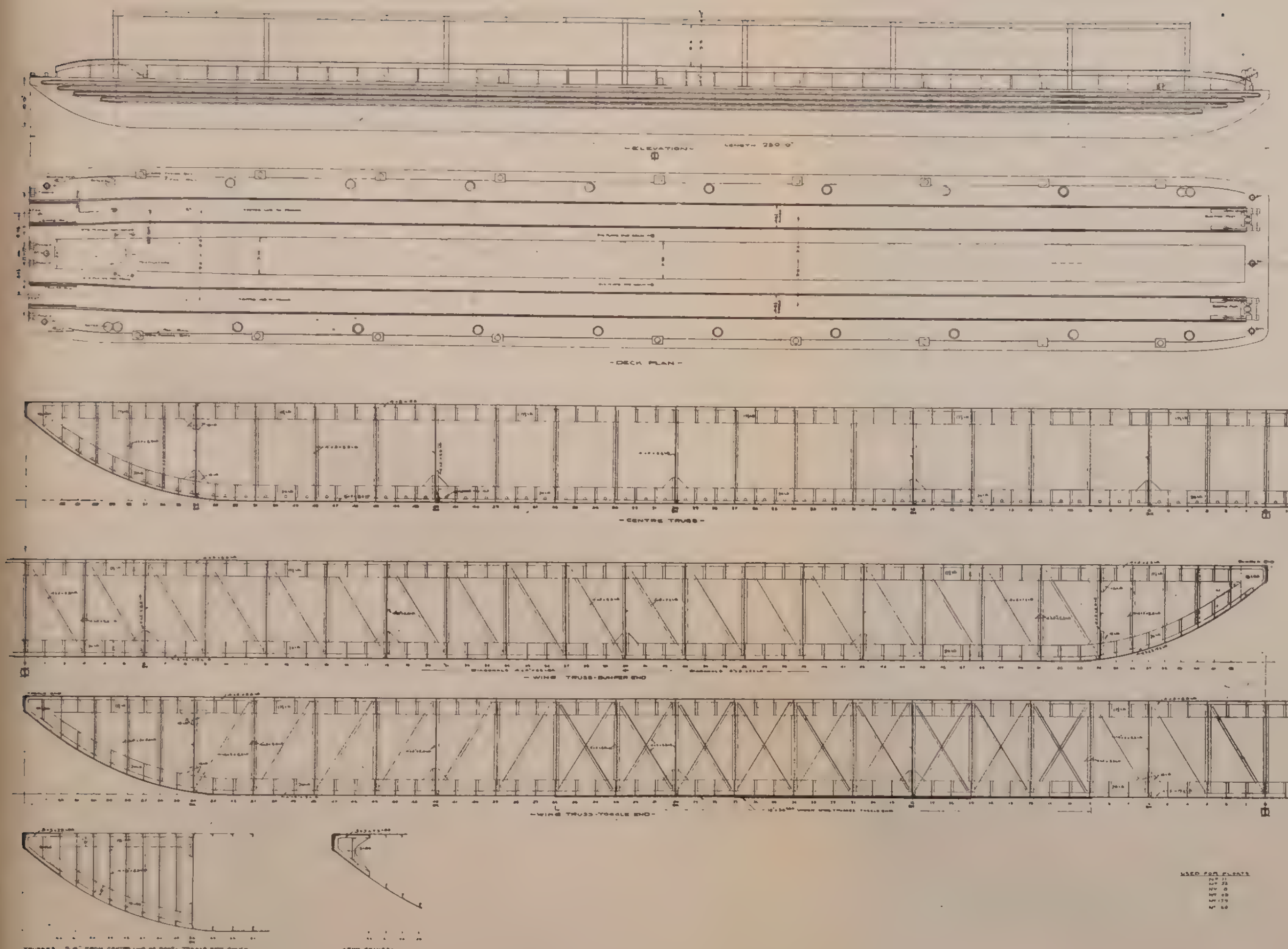


Plate 7A. Car Float, Pier and Transfer Service.

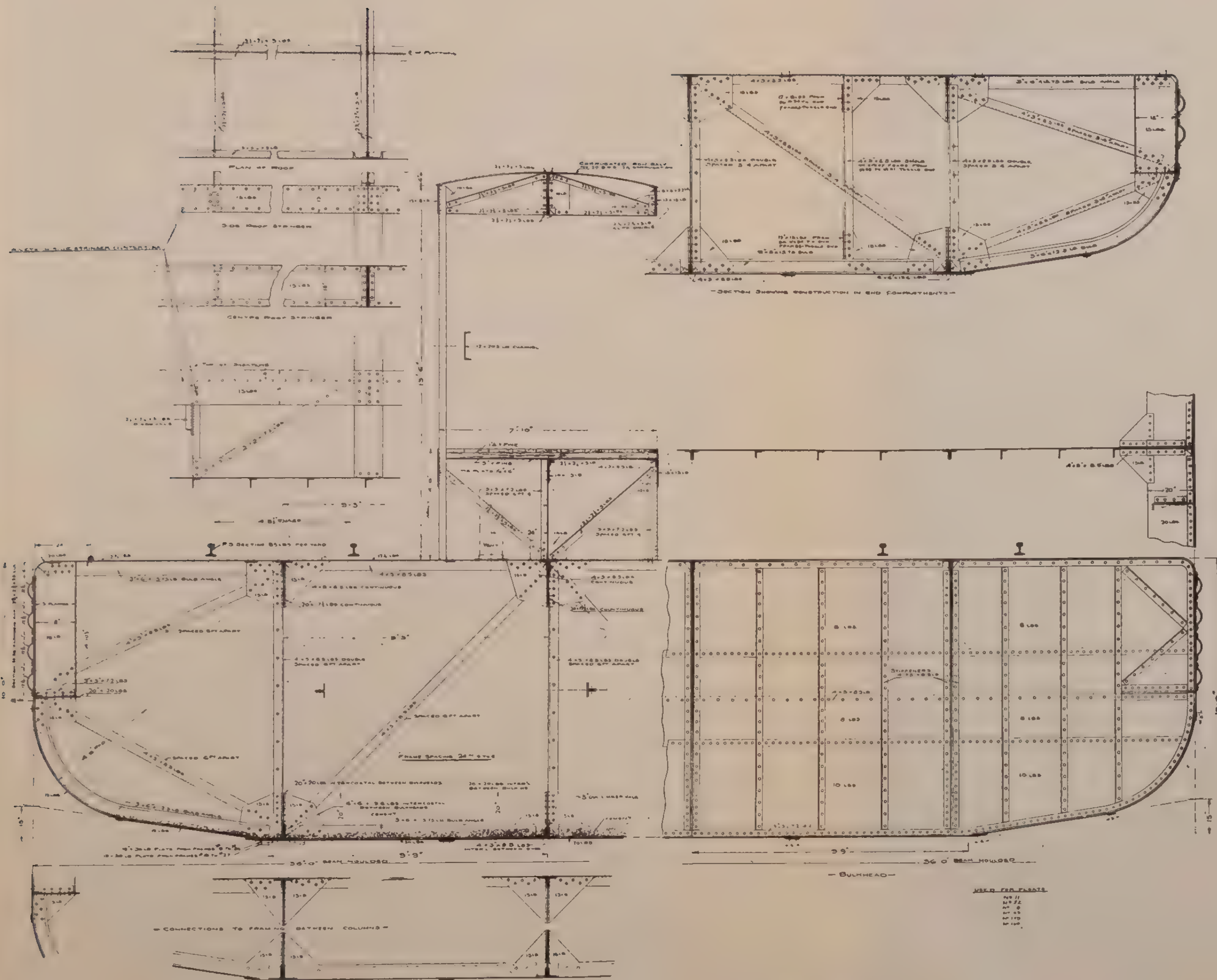


Plate 7B. Amidship Section of Car Float, Pier and Transfer Service.

heaviest loads and not too large for pier service; this compromise float is shown on Plates 7A and 7B.

One of the most interesting problems involved in this float movement is in loading and unloading them. Plate No. 8 shows the device employed. The height of the shore is constant, but the height of the float naturally varies with the stages of the tide; the floats are loaded over their end. Drill engines move the cars over tracks on the float that are a continuation of the tracks on shore. A "bridge", installed between the shore and the float, hinged at its shore end and with its outer end attached to the end of the float, completes the continuous track. The outer end is free to move up and down to accommodate itself to the exact height of the float. Naturally, the grade on the bridge will increase with increased variation in the height of the water and, therefore, of the float; it follows that the length of the bridge is governed by a permissible grade. The bridge joint at the shore end and at the float must be abrupt. It has been found that the permissible grade is not governed by the ability of an engine to push the cars, but by the vertical angle resulting at the joints; too great an angle permits the couplers on the cars to slide up or down sufficiently to allow them to disengage; 3° is the maximum safe angle when the center of the car truck is 5 ft. 10 in. away from the coupler, as is usual. Great differences in tide level could be provided for by extremely long bridges, room for which is not always available, so that it has become the practice to introduce articulated bridges, each joint being individually supported and operated, and their number depending upon the difference in tide levels at the localities where used. A single-span bridge is satisfactory at Norfolk, Va.; two spans are used in New York, and three spans are used in Maine. The first span is of the through plate-girder type bridge, about 75 feet long; the outboard end of this bridge is supported from an overhead girder by four vertical lifting screws, on each of which a nut is turned by worm gear driven by electric motors on a common driving shaft. Where sufficient lifting force is provided to operate this end of the bridge with its maximum load, the length of the span may be reduced. The second span, usually called an "apron", the outboard end of which is attached to the float, is made of wood and is usually

about 35 feet long; it must be designed so that the platform will endure considerable twisting. The float is made fast to the apron by heavy chain moorings, and alignment of track vertically and transversely is maintained by inserting four steel toggle-bars, five inches square, that pass horizontally through

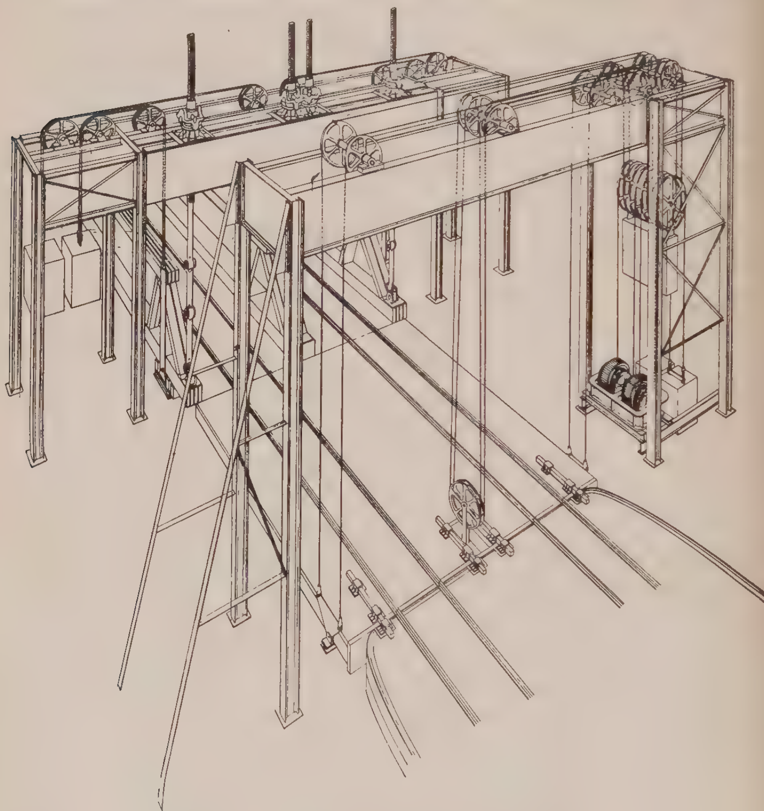


Plate 8. Car Transfer Bridge, Float Service.

eyes or pockets on the apron into similar pockets on the float, directly opposite. When one side of a float is being loaded it naturally lists to that side and must carry with it the end of the apron to which it is attached; the inshore end of the apron cannot list, as it is hinged to the bridge; twisting of the apron must therefore take place and is arranged for by a suitably designed structure. As the cars move over the end of the float

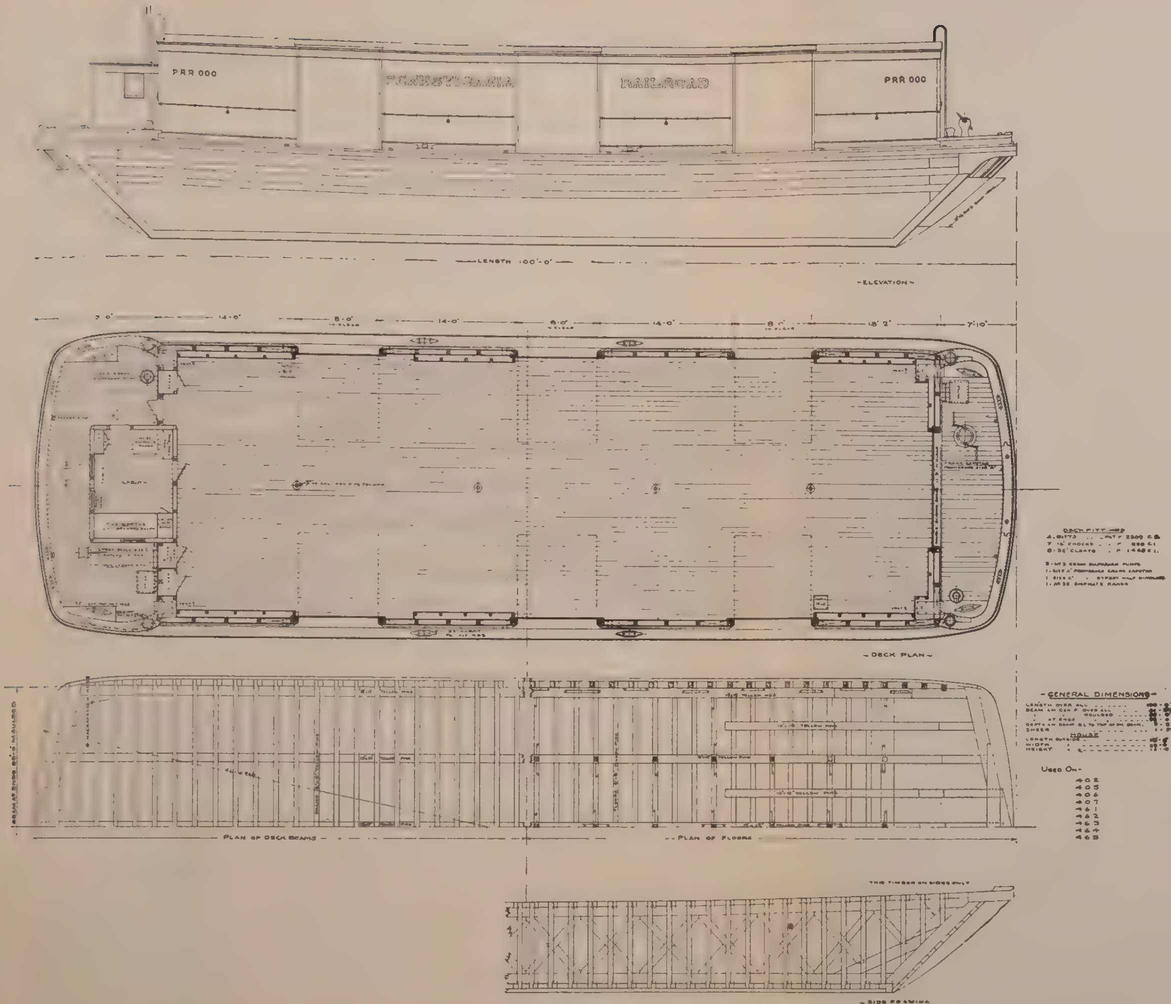


Plate 9A. House Barge.

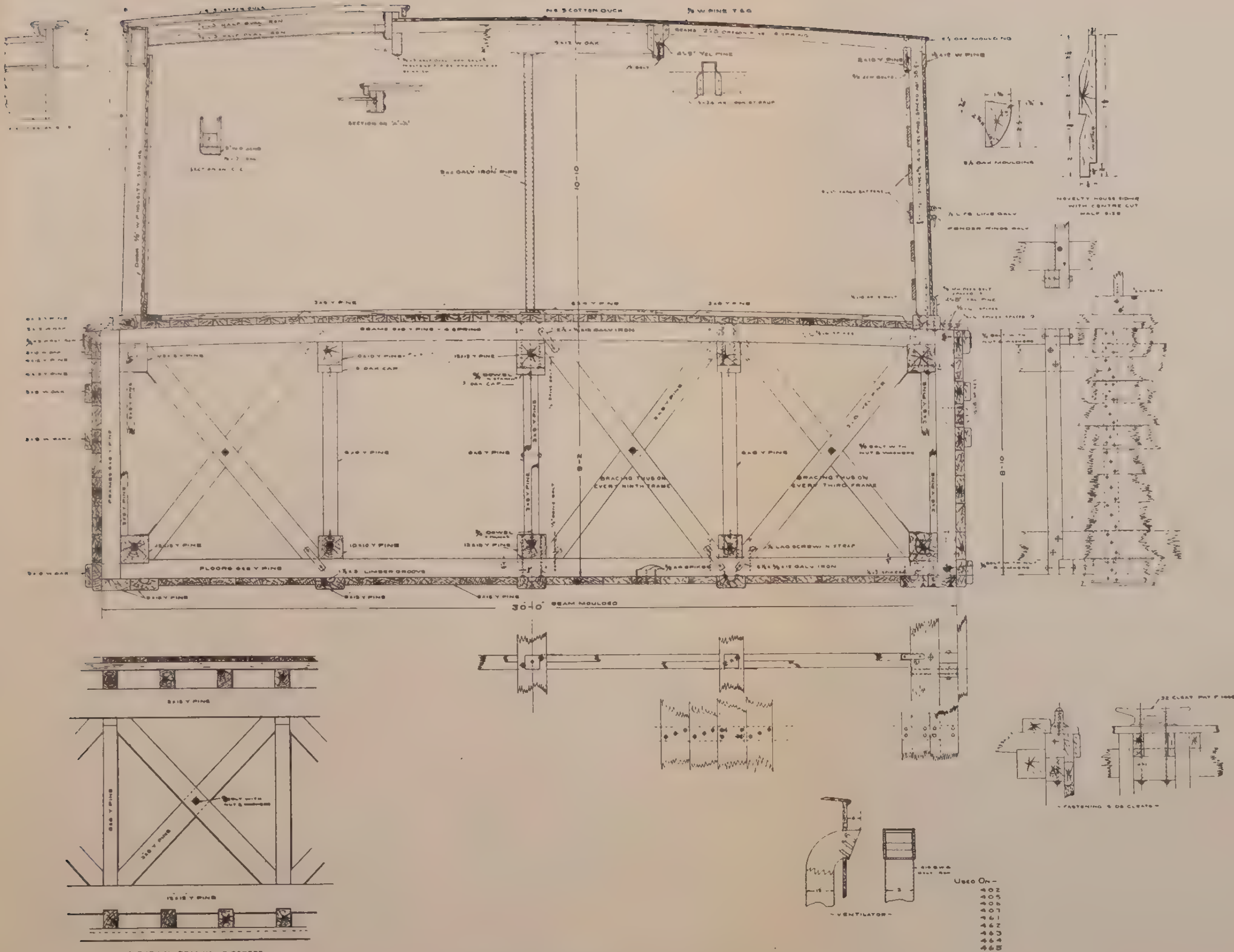


Plate 9B. Amidship Section of House Barge.

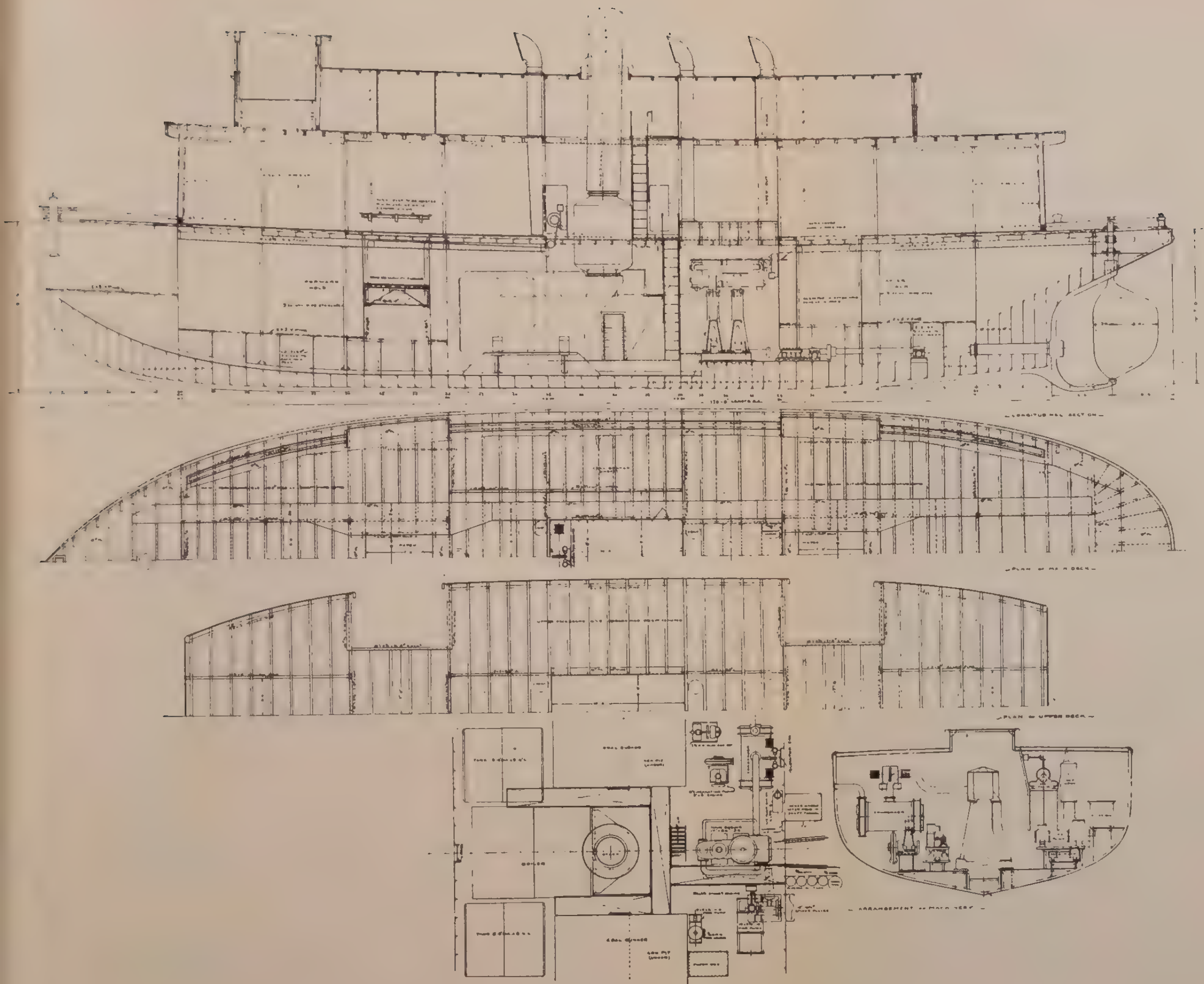


Plate 10A. General Plan and Interior, Self-Propelled House Barge.

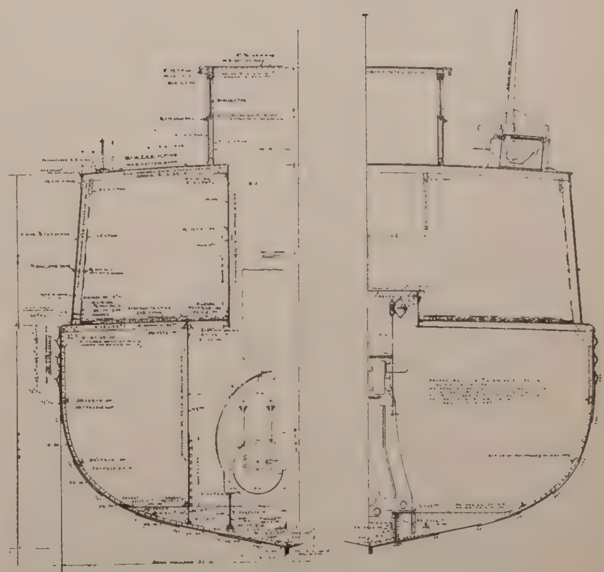


Plate 10B. Amidship Section, Self-Propelled House Barge.

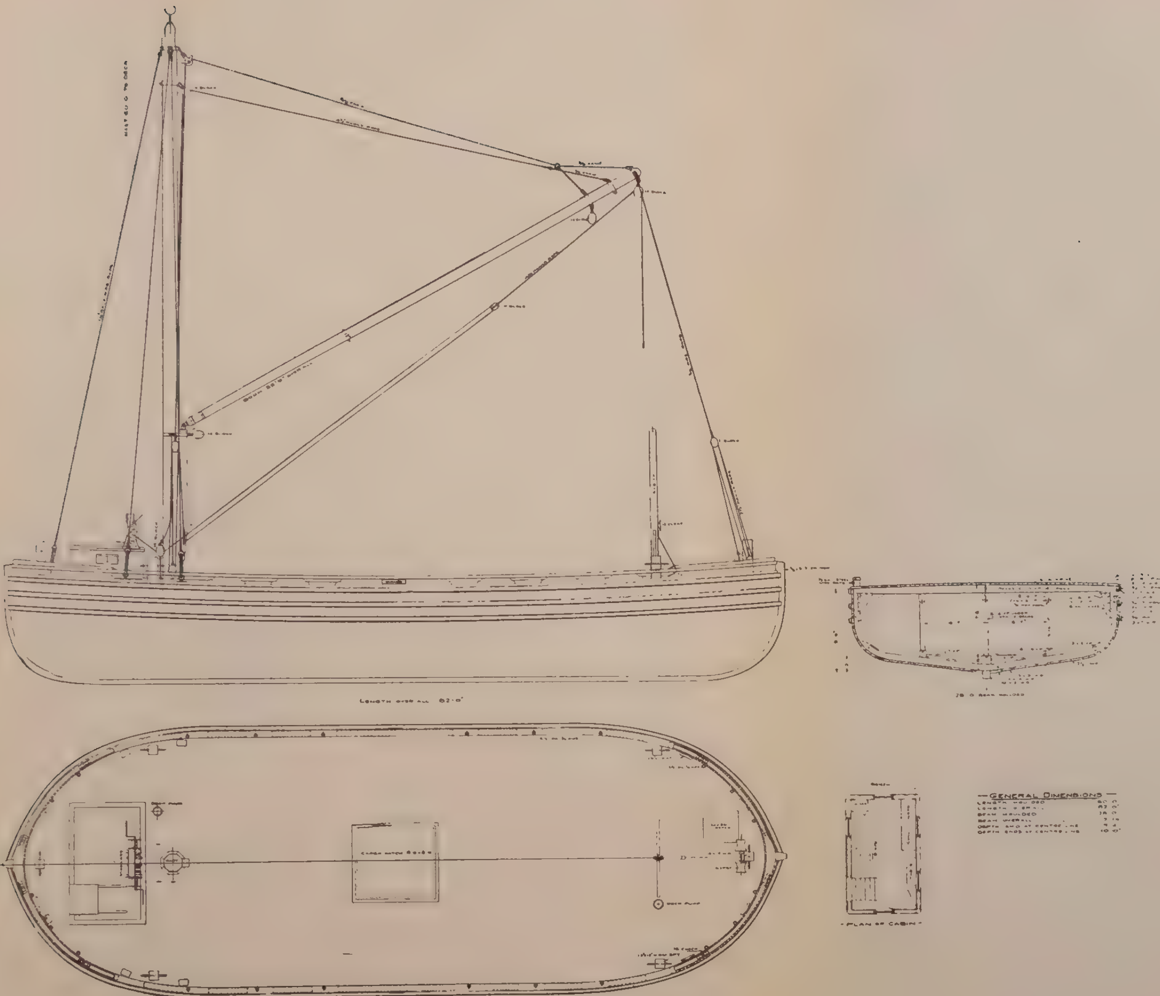


Plate 11. Hand Derrick Barge.

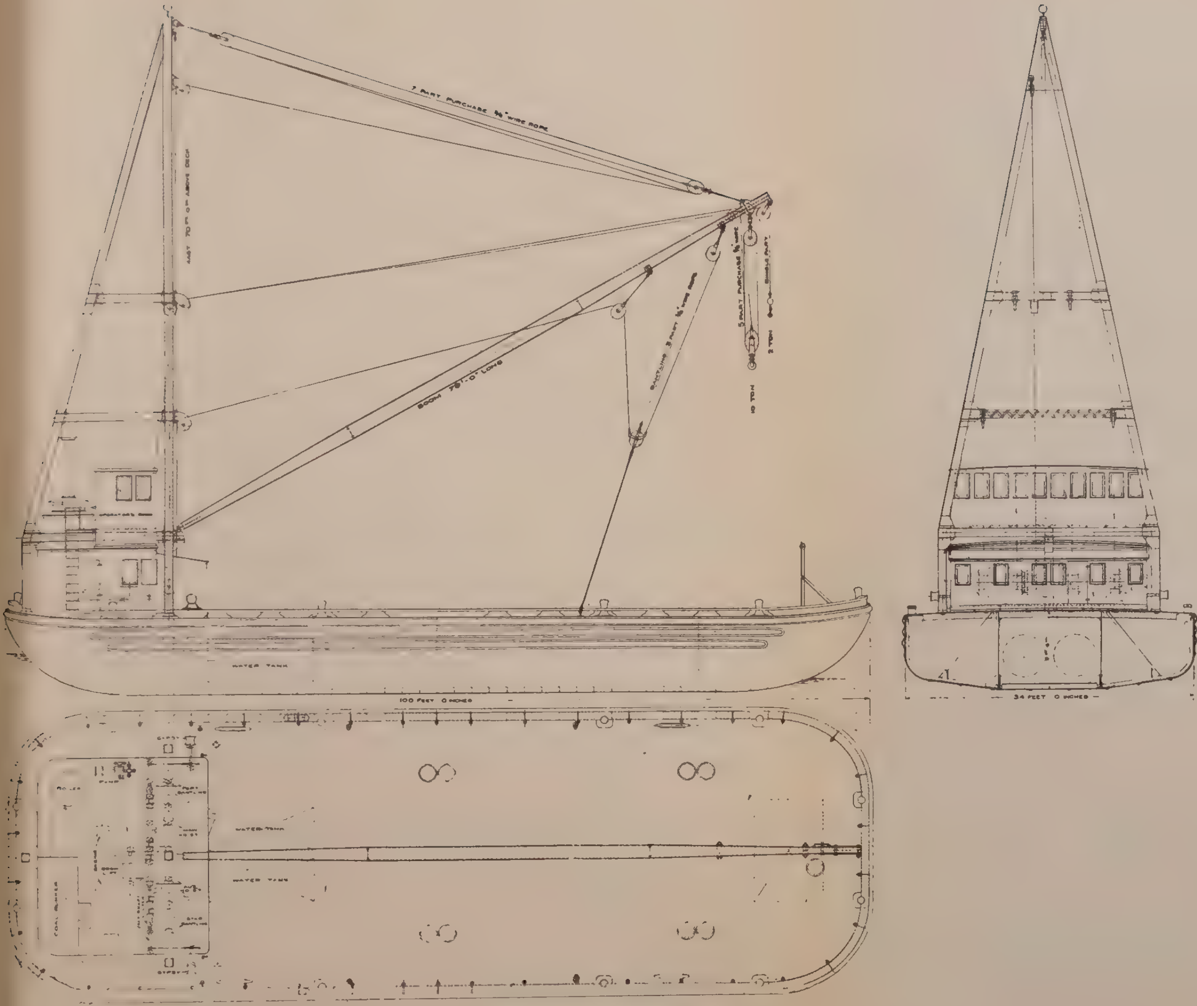


Plate 12A. Steam Derrick Barge.

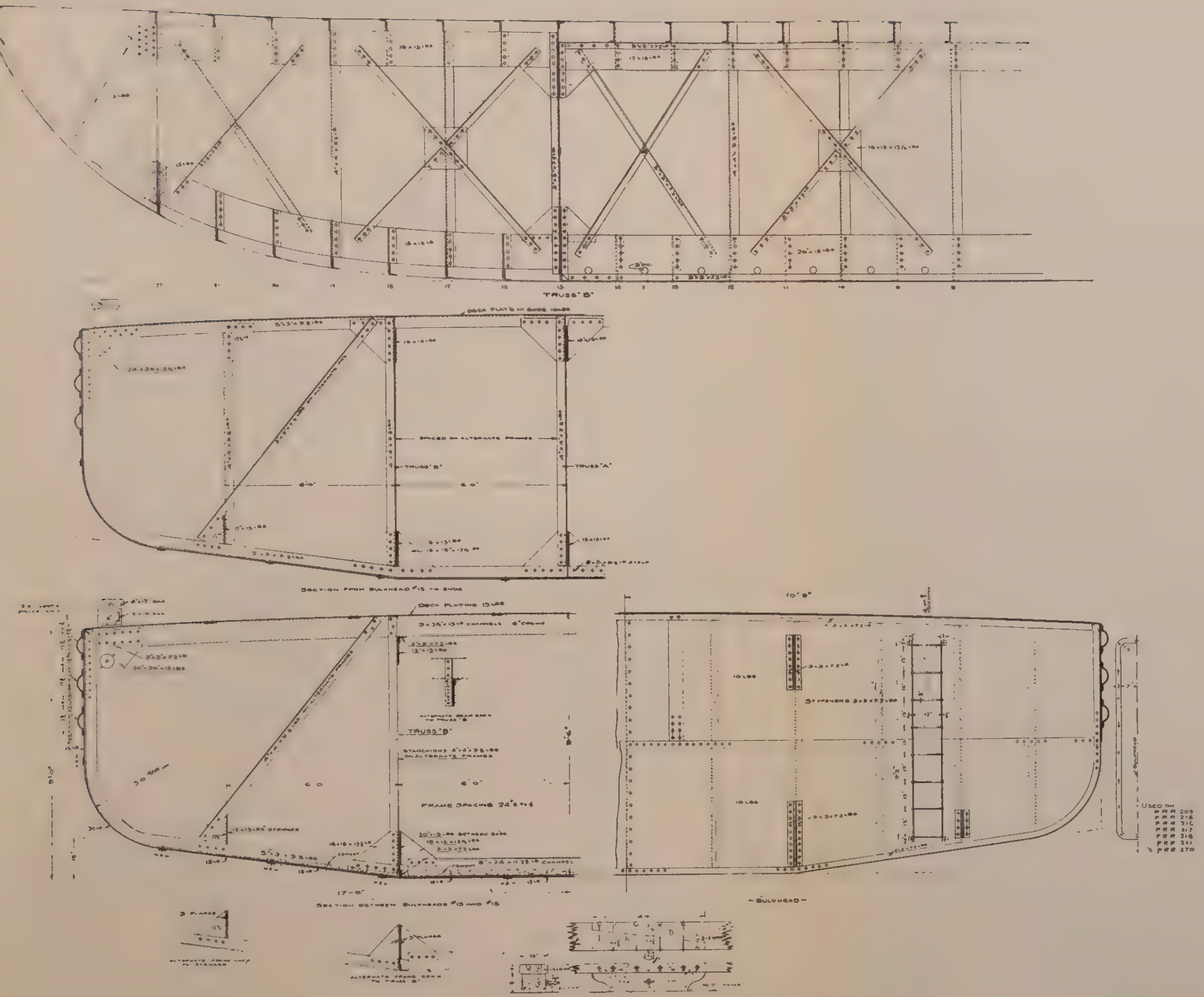


Plate 12B. Structural Arrangement, Steam Derrick Barge.

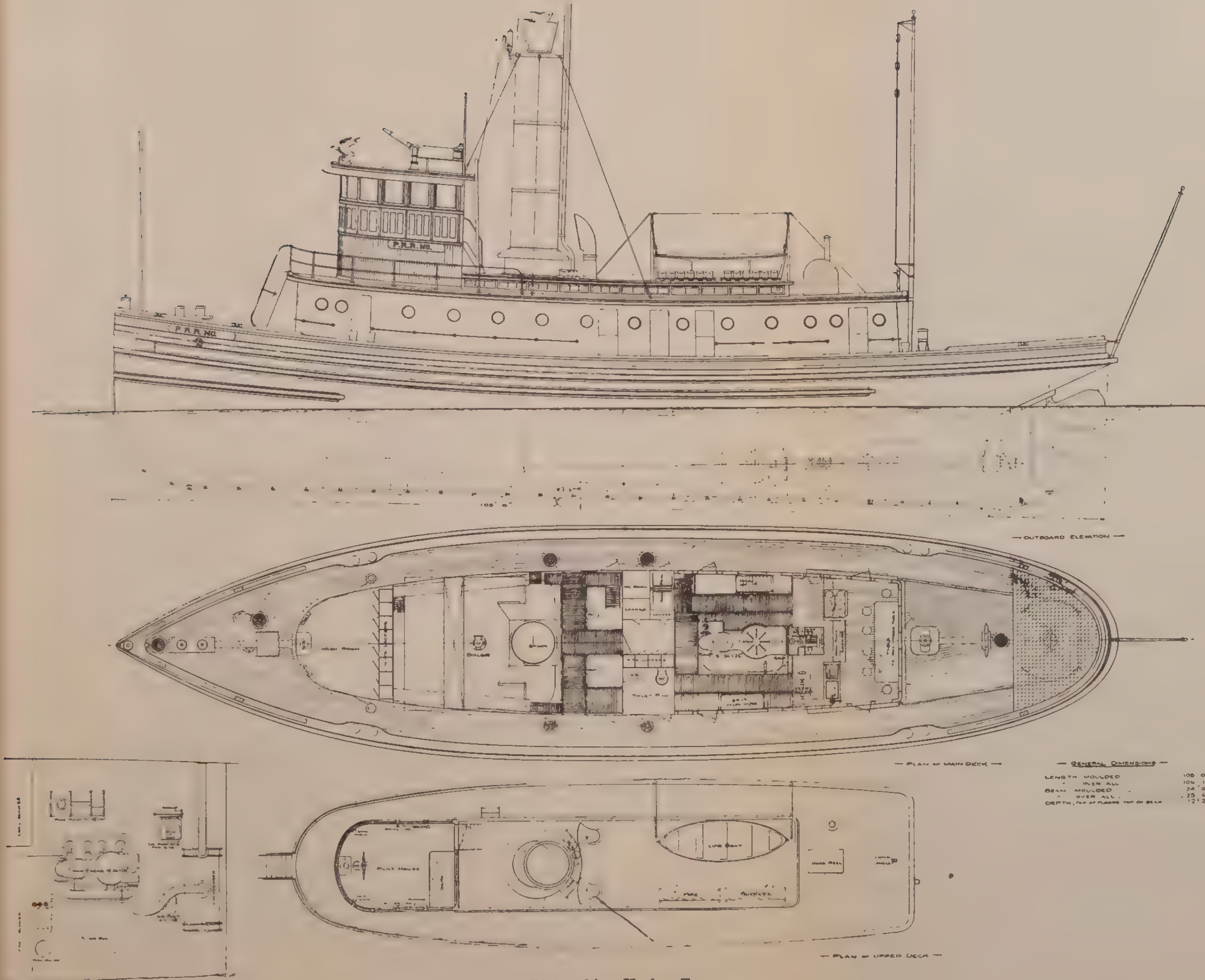


Plate 13A. Harbor Tug.

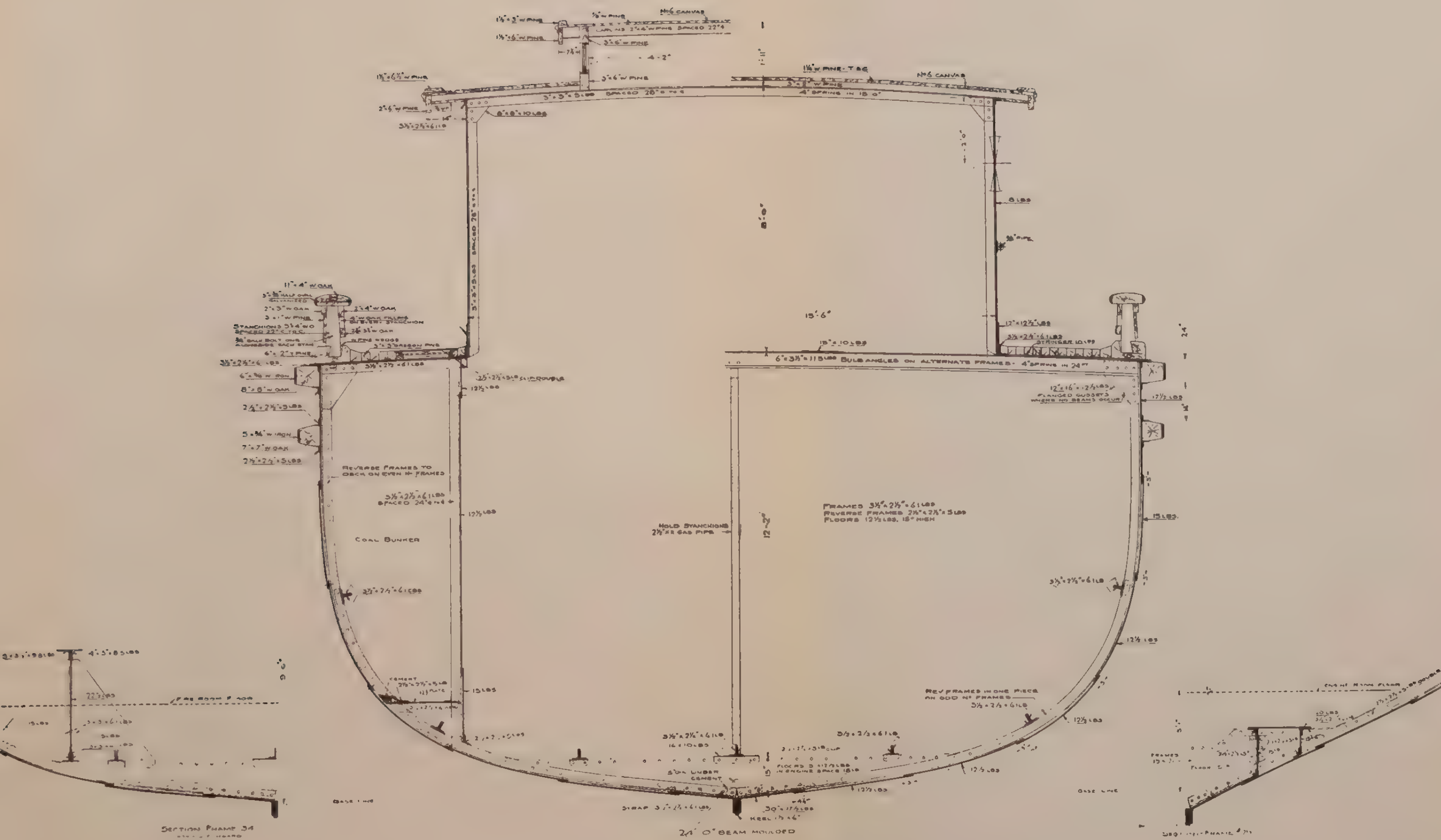


Plate 13B. Amidship Section, Harbor Tug.

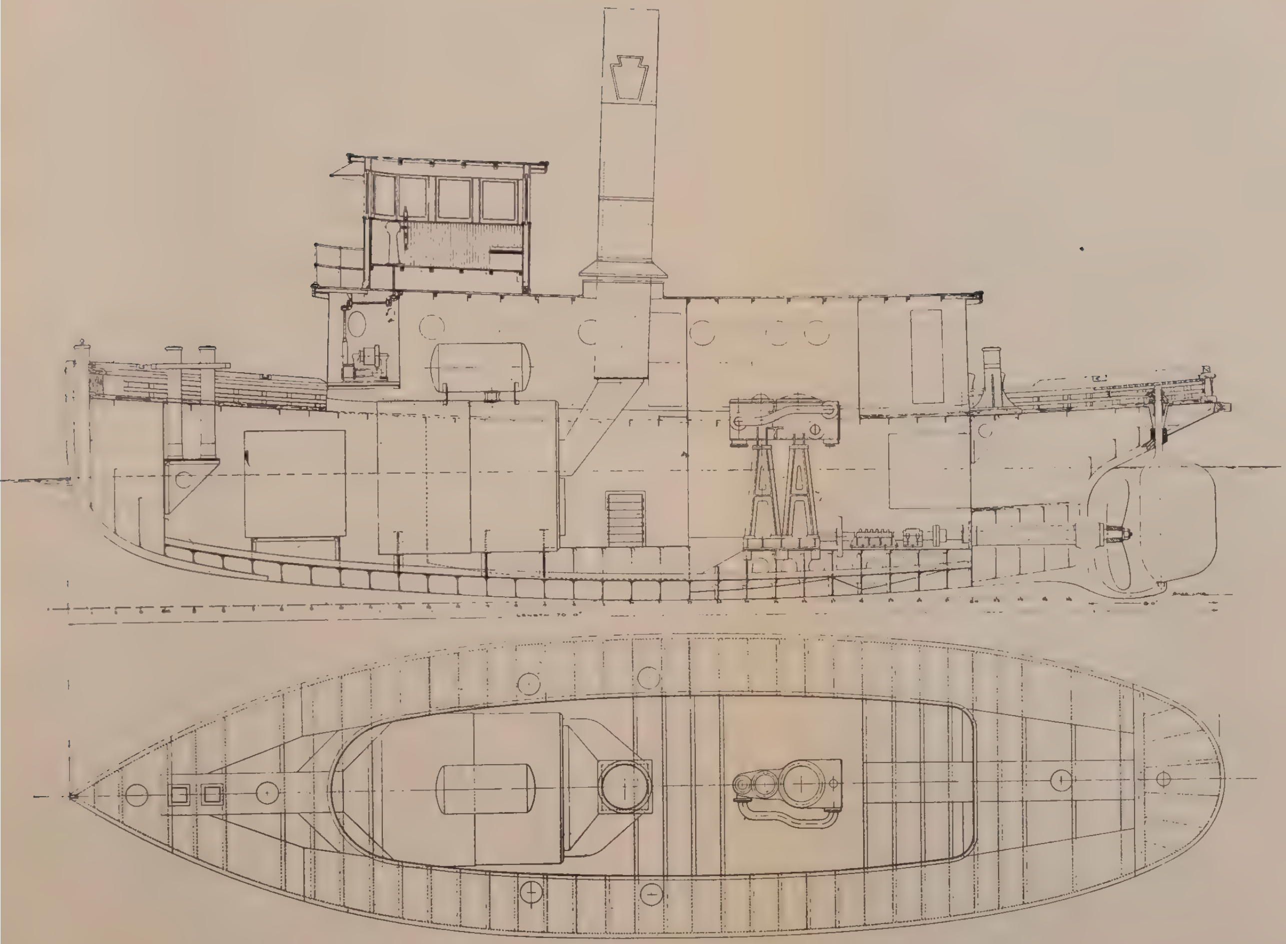


Plate 14A. General Plan Interior, Drill Tug.

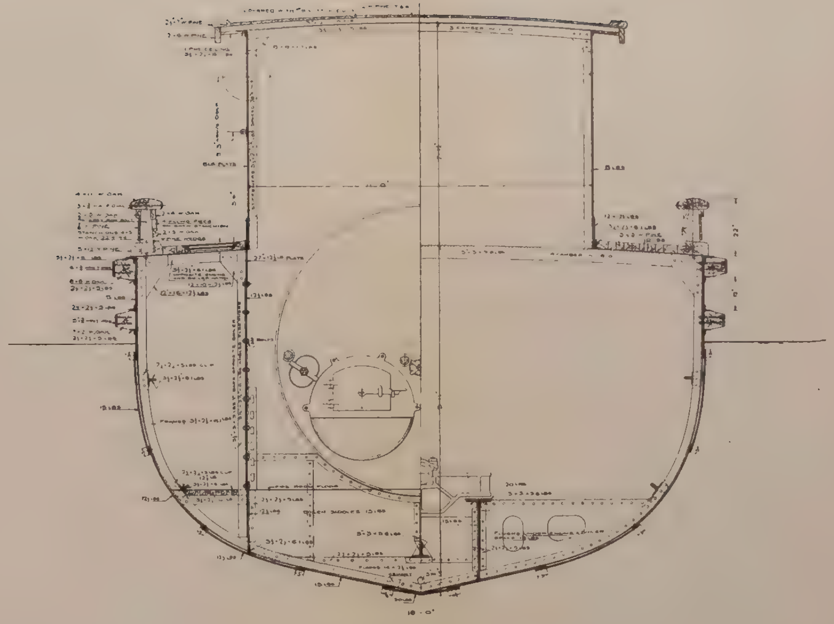


Plate 14B. Amidship Section, Drill Tug.

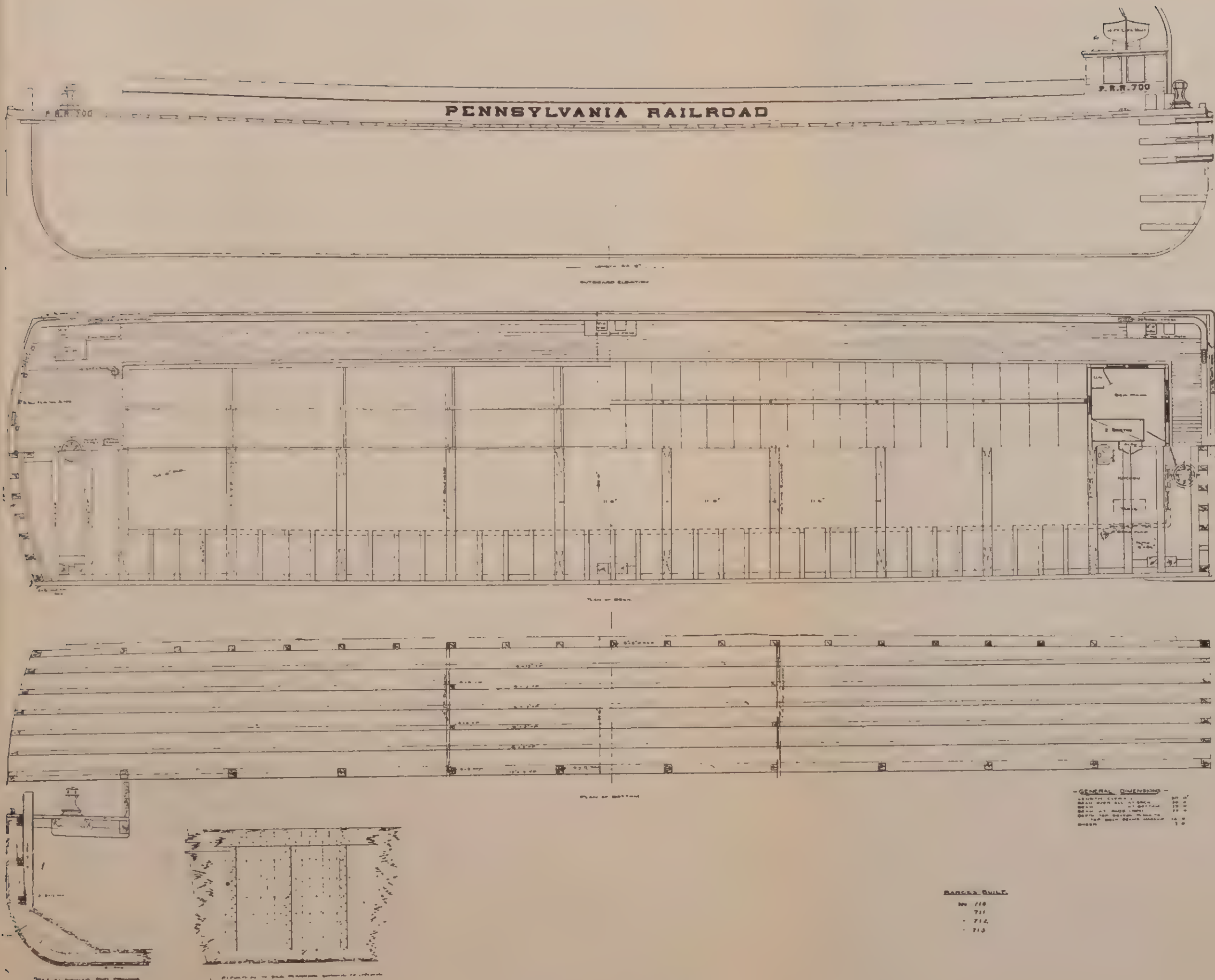


Plate 15A. Coal Barge.

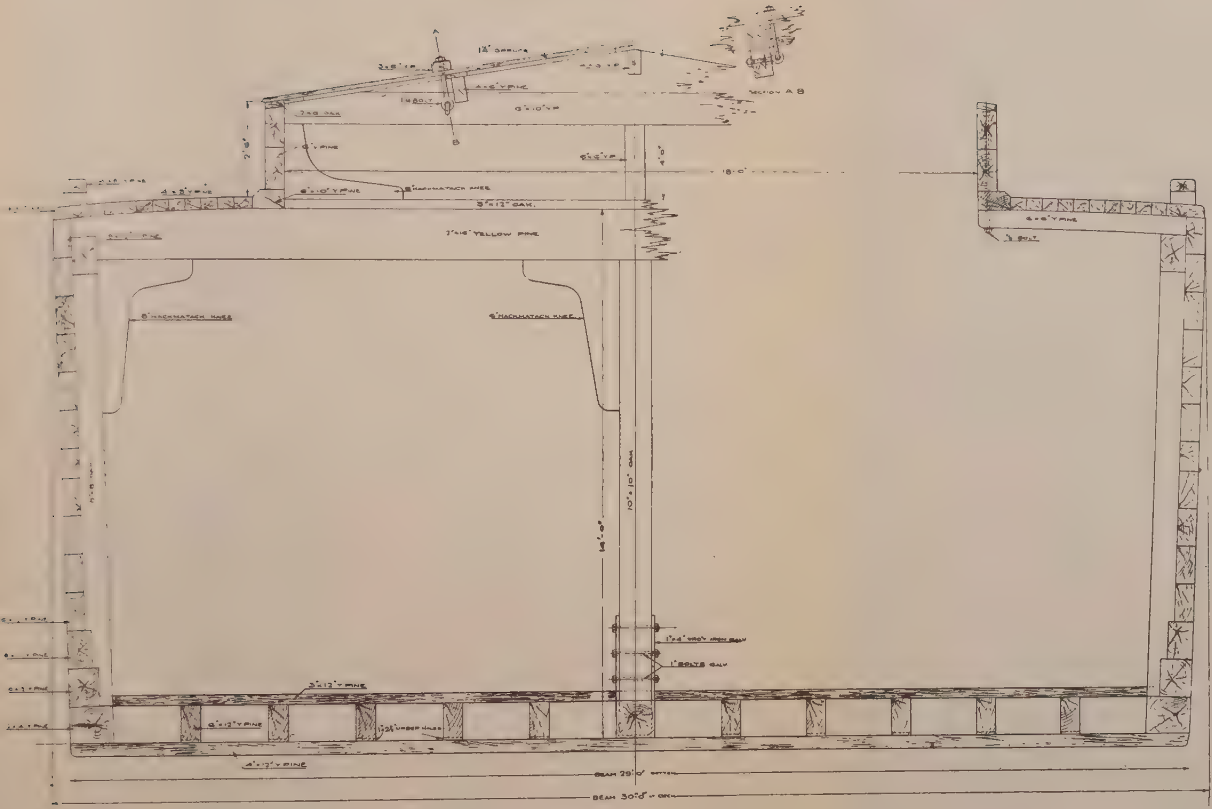


Plate 15B. Amidship Section, Coal Barge.

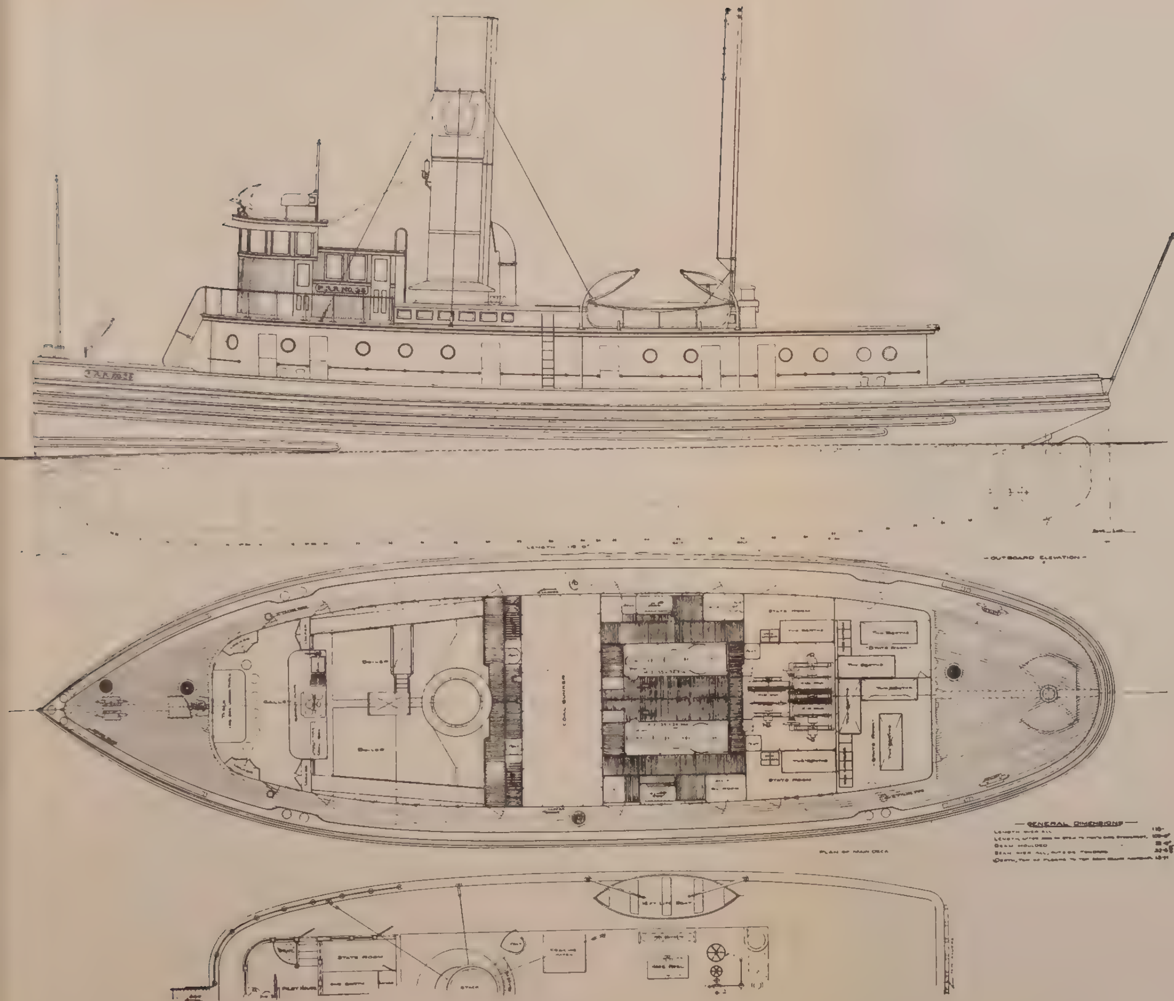


Plate 16A. Tug used for Towing Barges.

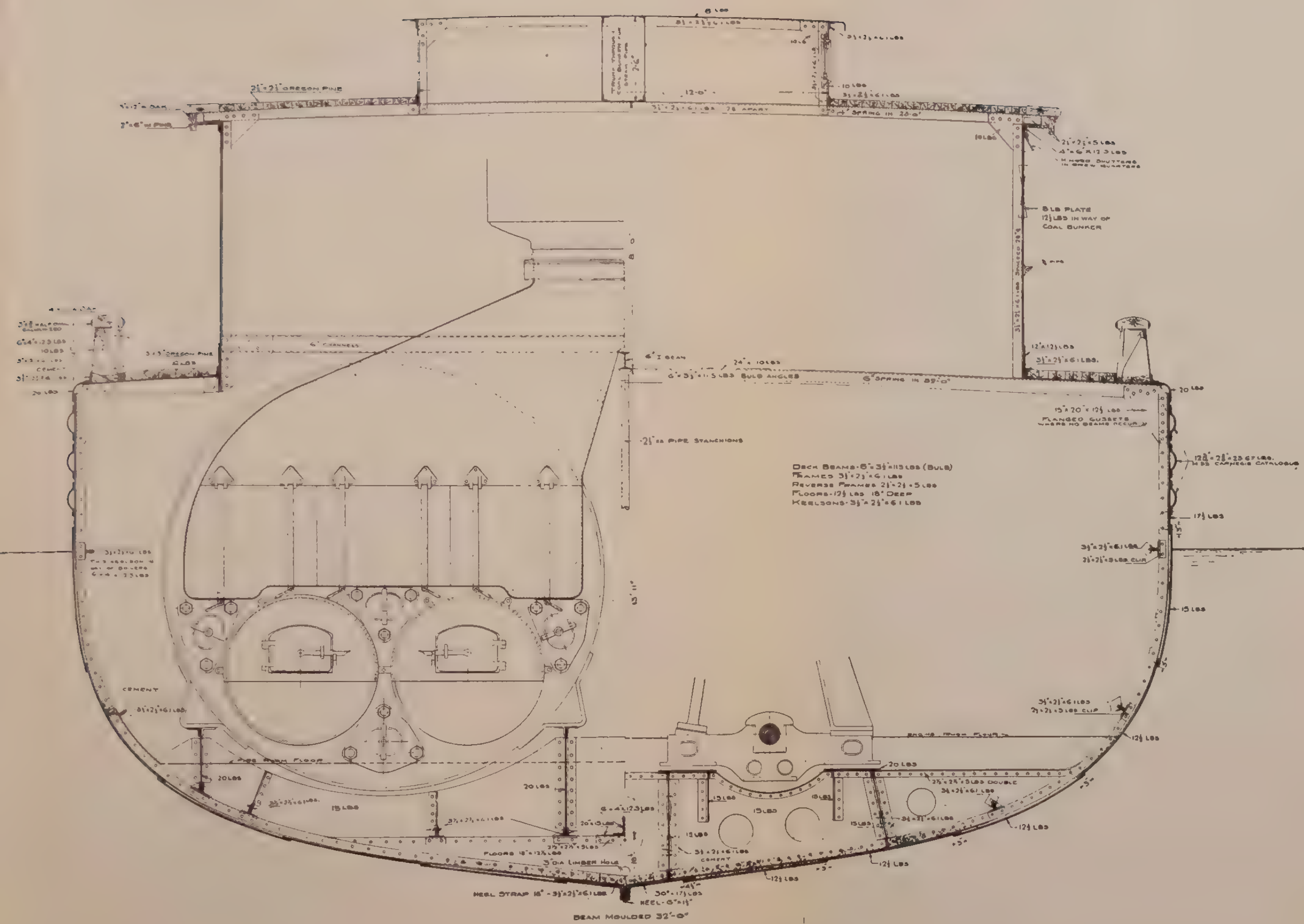


Plate 16B. Amidship Section of Tug used for Towing Coal Barges.

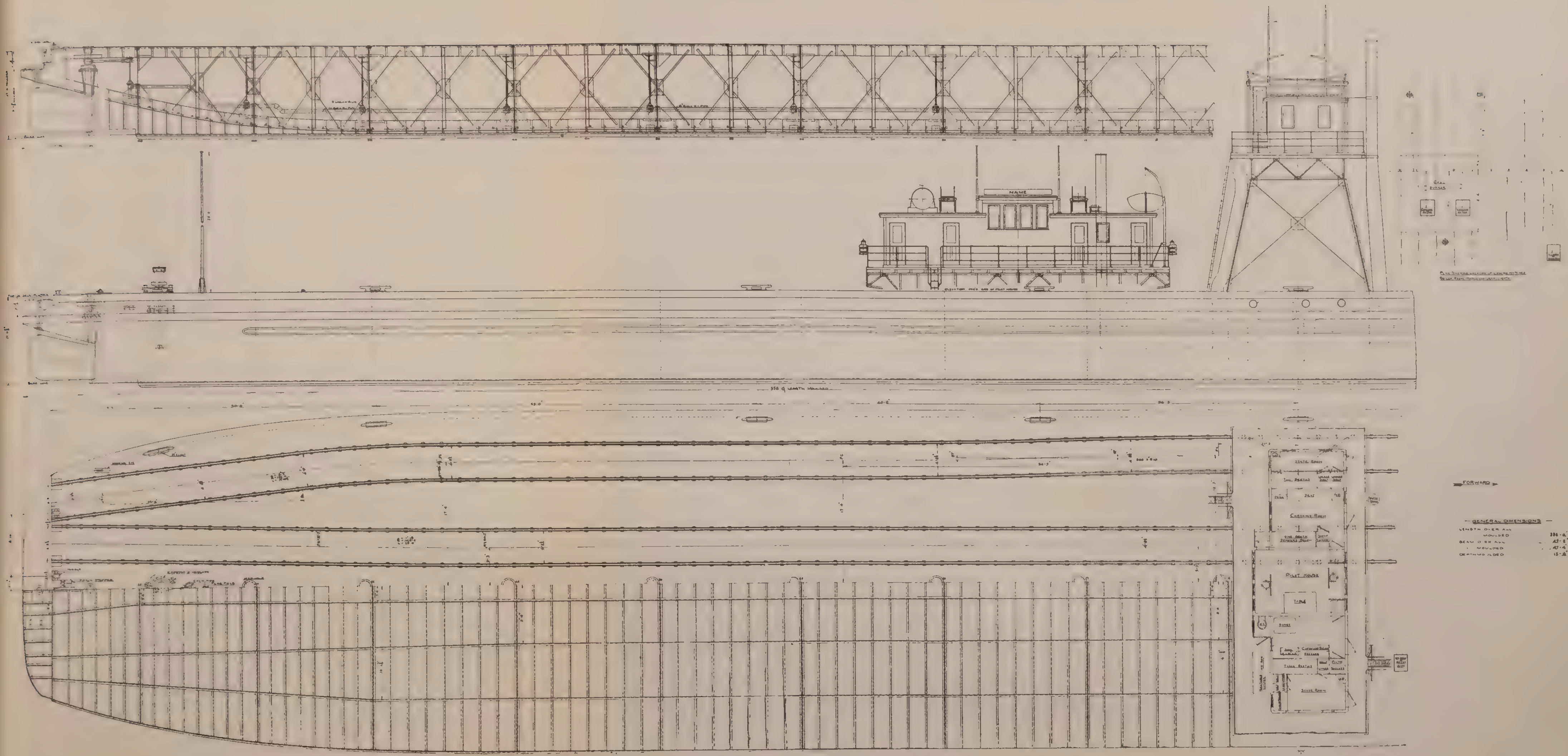


Plate 17A. Chesapeake Bay Car Float.

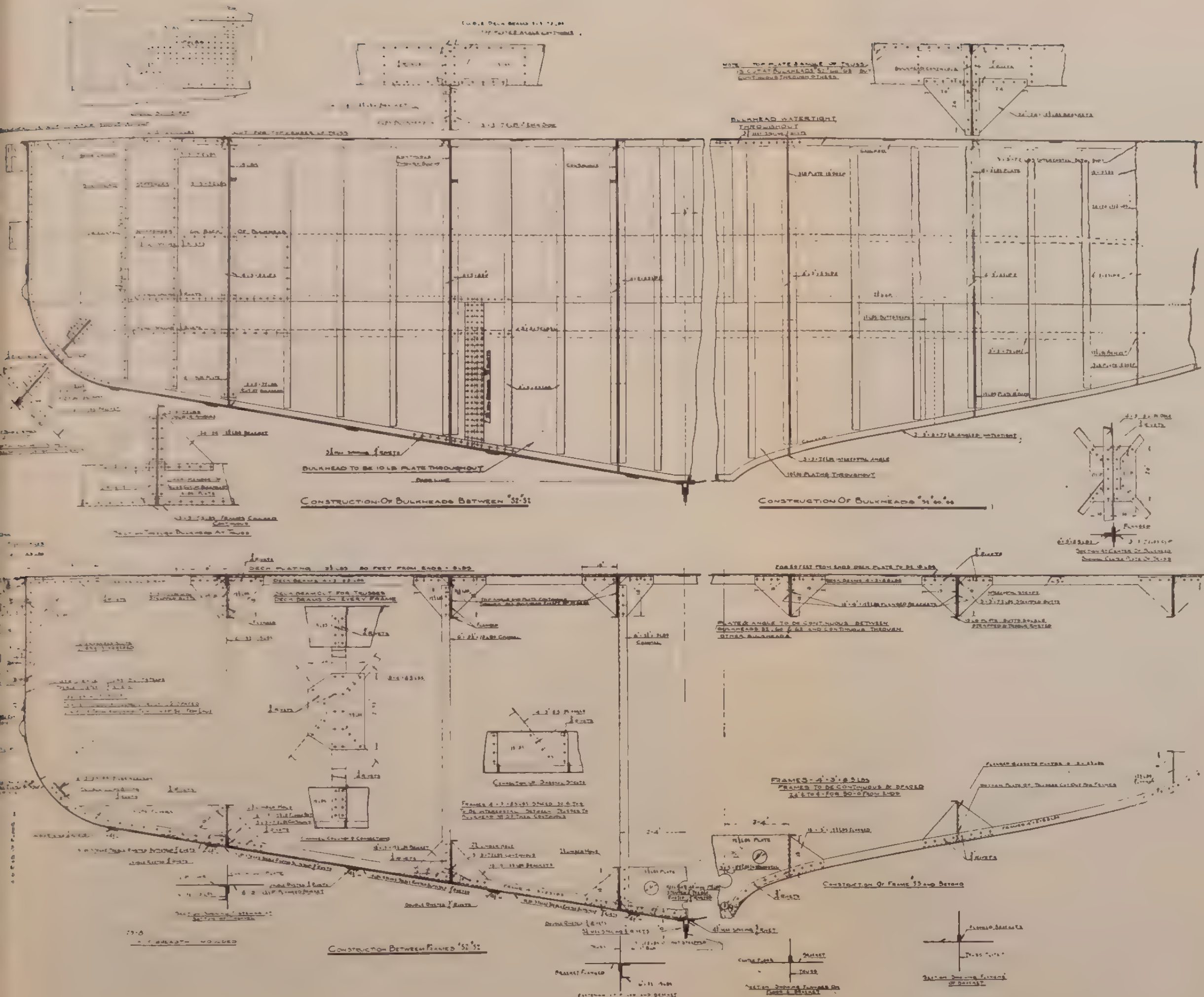


Plate 17B. Amidship Section, Chesapeake Bay Car Float.

a weight of considerable magnitude is thrown thereon which it is difficult to provide for in the structural design without considerable expense, especially in long floats; further, this weight would immerse the end of the float and, consequently, increase the "joint angle" above referred to as controlling the grade. To relieve the strain on the float and reduce the joint angle, an arrangement is provided to automatically counterbalance the live load. The ends of a wire rope are made fast to the outer end of the apron, the rope passes overhead around pulleys and downward until its loop rests in a sheave; on the shaft carrying this sheave is a similar sheave over which a wire rope passes, one end of which is attached to the drum of a hoisting engine and the other to a counterweight resting on the ground. When the apron is light it may be raised and lowered by the hoisting engine, but when a load comes on it is counterbalanced to the extent of the counterweight. Some space has been given to a description of this device, as so much has been said at various times of specialized vessel-loading devices; here is a facility which has been developed by degrees and unnoticed, and which will load 1,500 tons on a vessel in five minutes. Floats are moored, unloaded, reloaded and depart in twenty-five minutes at the type of bridge above described, with the further and greater advantage that floats may be made of less strength, and, consequently, at less cost and of less weight.

The delivery of freight to steamship piers, to manufacturing plants not equipped with float bridges, and to public piers is made by barges and lighters.

"Covered barges" are used for "perishable" material, which term covers a larger field than its name implies, as it means almost everything that could be affected by the elements. These barges are built of wood, usually about 100 feet long; the deck is housed over, and sliding doors are fitted along the sides —Plates 9A, 9B. A few of these are provided with stoves for heating the interior in winter, and ice boxes to cool them in summer. These barges are docked alongside covered piers maintained by the railroads at their rail terminals and confined to box-car freight. The tracks extend the length of the pier, and freight is unloaded directly from the car to the barge wherever delivery arrangements will permit. Unfortunately, this is not

always possible, and the storage and rehandling of a considerable amount of freight on the piers is a waste that it seems impossible to overcome. The freight is moved on hand trucks; while various mechanical devices have been tried, none has been found to be economically successful; the small electric truck with low platform is the nearest competitor and this can be made to handle some classes of freight more economically than the hand truck. The barges have a capacity equal to seven cars, but they are seldom fully loaded, as a consignment rarely calls for this exact amount; for adjacent distant deliveries several consignments will be loaded in one barge, but for delivery to nearby points it is frequently more economical to put only a few car loads in a barge and complete the delivery of the shipment. Supplementing these house barges, a self-propelled type is growing in favor—a steel-hull boat 120 feet long, with the deck housed over, having a capacity equal to twelve cars, as illustrated on Plates 10A, 10B. Originally designed for the quick delivery of certain classes of freight, its functions have been largely extended, as it has been found that for small shipments it is a strong competitor, in efficiency, with the towed barge. These vessels are loaded at night with a large number of consignments and make deliveries to the various piers during the following day. They carry a crew of stevedores, so as to avoid delay in unloading on arrival at a pier. The vessels have a speed of about 10 knots, and the form of the hull and the efficiency of their steering arrangements permits them to pass rapidly from point to point and maneuver quickly about the always crowded piers.

Open freight is handled on barges, or lighters, as generally termed, on which derricks take the place of houses; and because the weight they carry in units and in total amount is considerably more than is carried on house barges, more attention is given to their towing resistance. The smaller ones, shown on Plate 11, carry about 250 tons and are built of wood, with shipshape ends. The derricks on these are hand operated, of about 3-tons lifting capacity. Usually these boats are loaded by the cranes maintained by the railroads at their open piers, the boats' derricks being used for unloading at the delivery point. For heavier unit loads and increased capacity, steam-operated

derricks are installed on steel-hull barges about 100 feet long, shown on Plates 12A, 12B. These vessels will carry 450 tons; their derricks will lift 10 tons and are fitted with booms 75 feet long, so as to reach to a second or third track on a pier. Every movement of the boom is mechanically operated. Supplementing the towed barges, self-propelled vessels, following the lines of the self-propelled house barges, are used, where, of course, steam-operated derricks take the place of the houses, and are used in a similar manner to the house barges for the delivery of small consignments. Very few roads maintain floating equipment capable of transporting heavy and unusual unit weights; they depend upon one of the wrecking and lighterage concerns to perform this intermittent service.

To move the car floats and barges that are not self-propelled from point to point, tugboats are employed. These vessels take their ''tow'', when loaded, to the delivery point, and usually pick up a ''tow'' in the vicinity on their return, their work being confined to the business of the road by which they are employed. The crowded condition of the harbor requires them to take their tow alongside for better control, and for this reason their guards and deck must be very strongly constructed. In the design of these vessels, the prevailing idea is to install the maximum of power in the minimum of space, as, naturally, the smaller the vessel the more easily it is maneuvered—a most important feature. The prevailing type of tug used for towing car floats and the heavier barges is shown on Plates 13A, 13B; it is about 105 feet long, has 650 i. h. p., and a displacement of 300 tons. They are fitted with steam steering-gear, electric lights, fire-pumps and wrecking suction-hose. Most of these vessels are operated the full 24 hours, but their crews are not berthed on them, as they prefer to spend their time ashore when off duty. A smaller size tug, of similar design, is used for towing the smaller lighters, and a still smaller tug is used in the shifting of barges around the piers to place them in the most advantageous position for loading, doing on water what the ''drill engine'' does on land. The little boats, Plates 14A, 14B, have a form of hull particularly adapted for maneuvering, have ample steering facilities, and contain little else than their motive power.

The operation of this equipment is controlled from a central

office, where a record is kept of the location of each vessel, and orders to each are issued therefrom, these orders being usually transmitted by telephone to the nearest station where the vessel is expected to report; supplementing this method, "runners" are employed to expedite the unloading and releasing of barges at the various piers outside the company's stations.

The transportation of coal to Manhattan is, as might be supposed, an important feature. The domestic supply is provided for in two ways:—by car float delivery to a few stations reached over float bridges, and by trucking over the ferries—the latter method being the greatest in volume. Manufacturers adjacent to the water front and steamships take their supply from barges, which are in most cases loaded at rail terminals devoted entirely to coal and located some distance from Manhattan, the furthest being twenty-five miles. These barges are built of wood, box form, in various capacities up to 1,200 tons. A type is shown on Plates 15A, 15B. They are loaded from a trestle or by a car dumper and are then gathered together in a "tow" by a drill tug of the type above described. Hawsers are made fast, and the "tow" is then taken up by a tug of larger size and brought to the harbor for distribution; the barges are arranged three to four abreast and in tandem, until it is not unusual for a tow to contain twenty-eight boats. The most powerful tug used in this service is shown on Plates 16A, 16B. This vessel is built entirely of steel, is 118 feet long, has twin screws, and a total of 900 i.h.p. In making the journey, nature is called upon to assist, by arranging the departure so that the tide will always favor the voyage. On arrival in the harbor, assisting tugs will pick up the various boats, take them alongside, and deliver them to the various piers to which they are consigned.

The above describes what may be termed the floating equipment of a railroad. The size of each unit and its character vary considerably from those individually shown, but selection has been made of the most modern design and suitable size that experience has seemed to show to be the most appropriate.

The railroad between Cape Charles and Norfolk, Va., operates a float service that is unusual in results obtained, and

deserves notice. The route is over the Chesapeake Bay, and, in length, is about thirty-two miles. Heavy ice is never encountered and the ice-breaking type of vessel, as used on the Great Lakes, is not required. A fleet of floats such as is shown on Plates 17A, 17B has been installed. They are of steel, 358 feet long, carry four tracks, with room for twenty-eight to thirty cars, are equipped with steam steering-gear, and are subdivided into watertight compartments so efficiently that while they have been damaged by collision, none have yet been sunk. They are towed on a hawser by a tugboat, of 750 i.h.p., at a speed between seven and eight knots, as they are of very easy form. Undoubtedly, this service is an example of the cheapest and safest method of transferring cars by water.

To give an idea of the equipment necessary to conduct its business, a railroad that maintains the greatest amount of floating equipment has the following in New York Harbor: ten ferry boats, thirty-one tug boats, seven self-propelled barges, sixty-eight car floats, seventy-one covered barges, seventy-one derrick barges, and twenty coal barges.

Attached is a table giving the important dimensions of the equipment described herein.

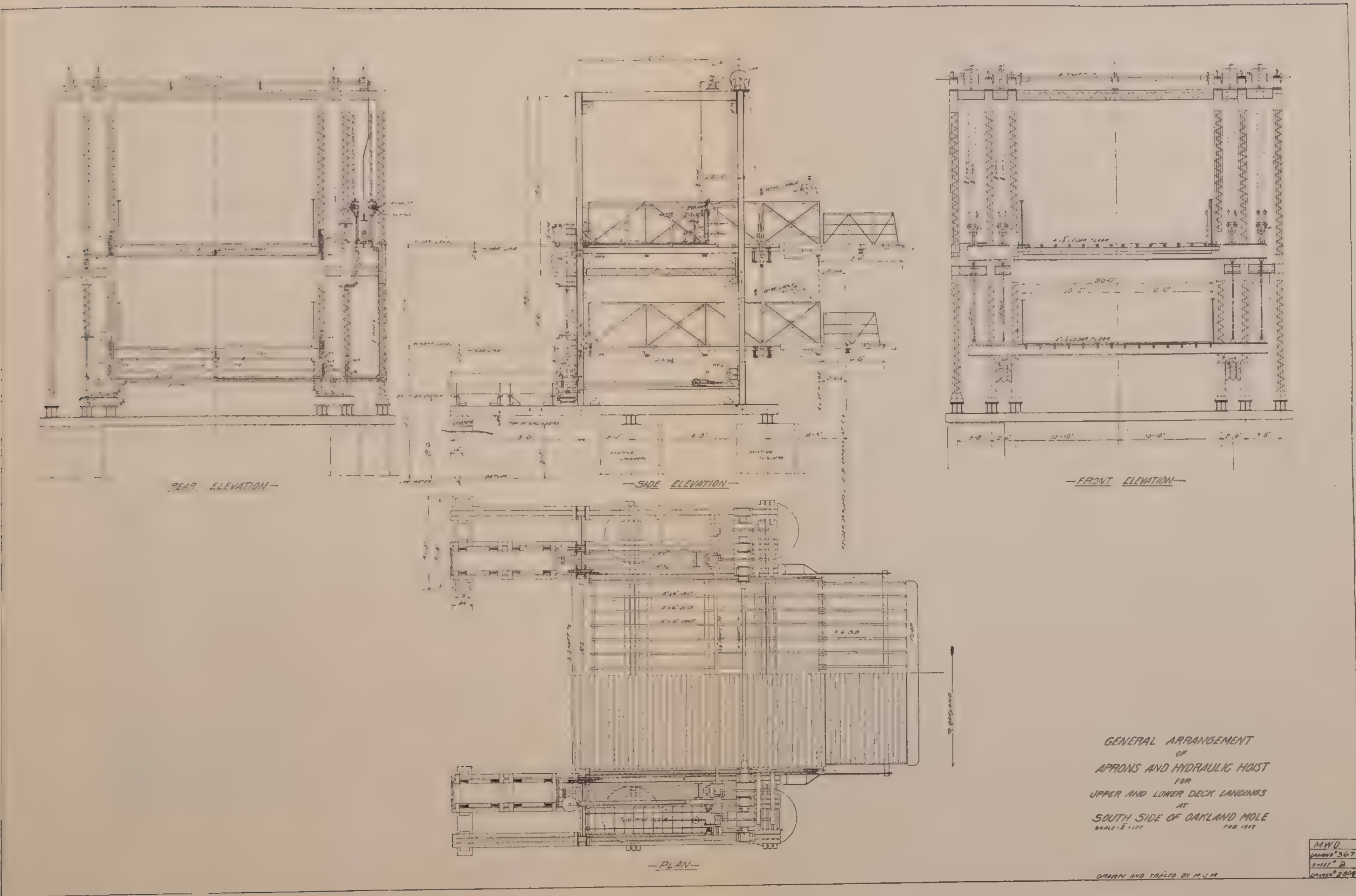
Principal Dimensions of the Various Types of Vessels in the Floating Equipment of a Railroad.

		Length		Beam		Depth		Displacement	Engines		Boilers			Propellers	
											Steam pressure	Heat'g Surface	Grate Surface		
		ft.	in.	ft.	in.	ft.	in.	tons	Dimensions	I. H. P.	lbs.	sq. ft.	sq. ft.	Dia.	Pitch.
Ferryboat	Plate 2	206	0	65	0	15	4	960	32″x22″x32″ / 24″	850	160	5052	112	9′ 3″	12′ 0″
"	" 3	168	0	55	0	13	2	600	26″x18″x26″ / 22″	700	160	3300	92	8′ 2″	12′ 6″
Tugboat	" 13	105	0	24	0	12	2	306	18″x36″ / 26″	665	160	2522	71.3	9′ 0″	12′ 6″
"	" 16	118	0	32	0	13	11	580	2 14″x21″x35″ / 24″	900	175	3946	112	8′ 6″	12′ 0″
"	" 14	70	0	18	0	9	11	145	14″x28″ / 20″	180	130	952	36	7′ 0″	11′ 0″
"	" 18	141	0	25	0	13	8	450	17″x24″x41″ / 30″	750	180	2455	78	8′ 8″	14′ 0″
Steam barge*	" 10	120	0	32	0	14	9	380	17″x34″ / 24″	330	125	1273	45.5	8′ 0″	12′ 0″

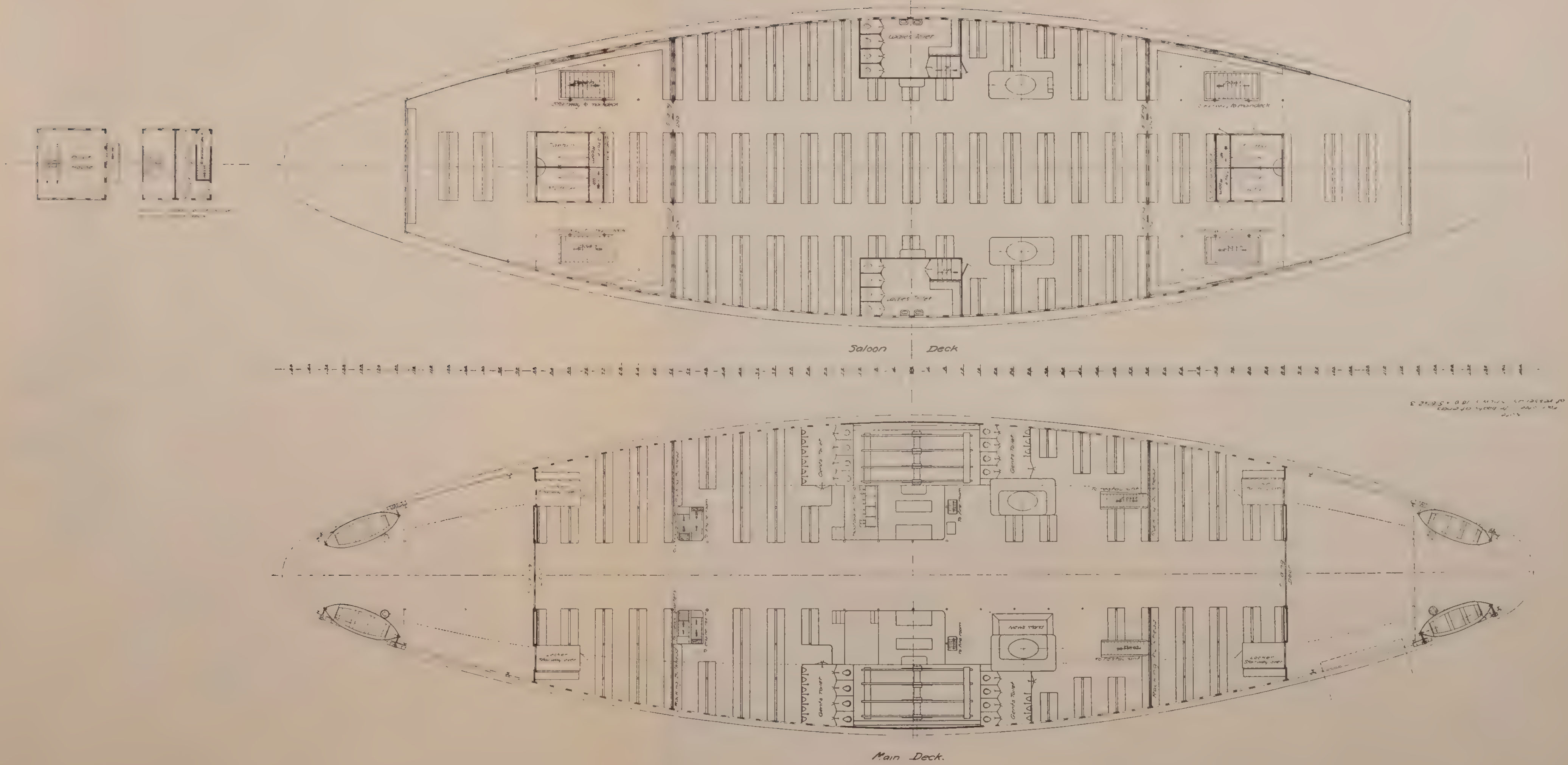
* The steam barge has a capacity equal to twelve cars.

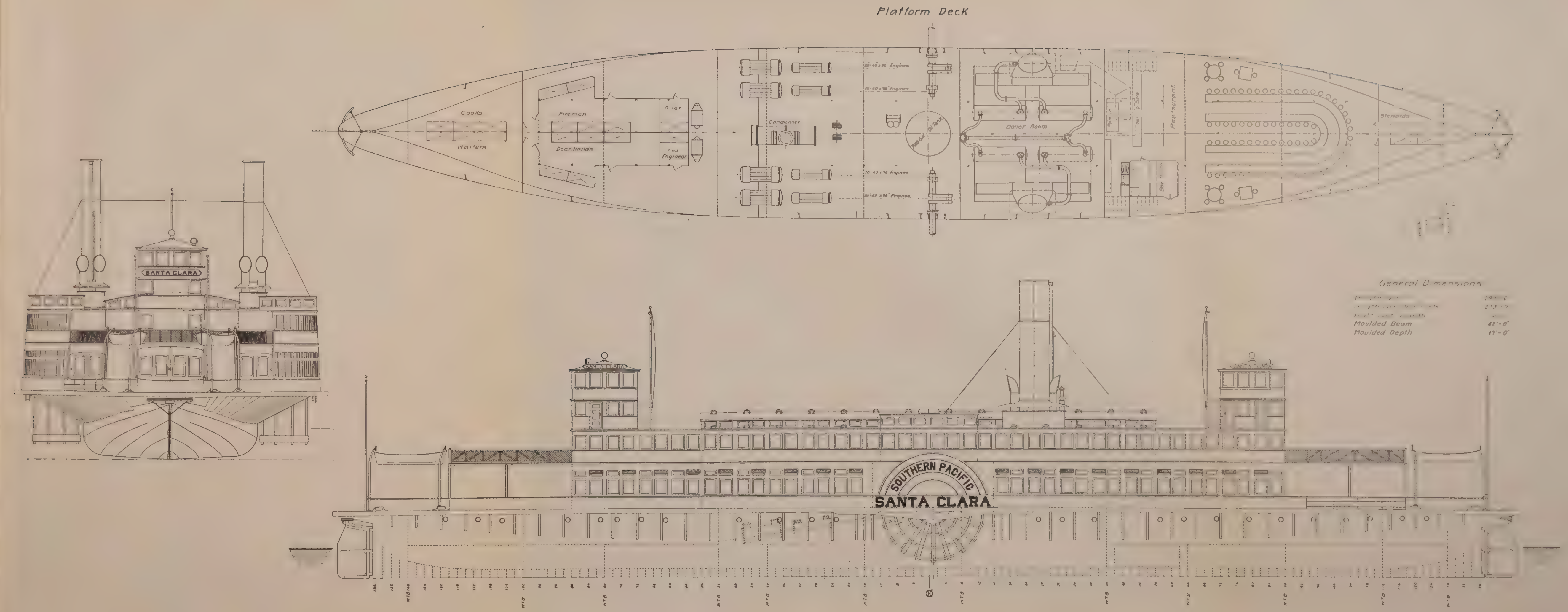
		Length		Beam		Depth		Capacity	Tracks
Car float	Plate 5	250	0	34	0	9	10	12 cars	2
"	" 7	250	0	36	0	10	0	12 "	2
"	" 6	340	0	38	0	11	0	22 "	3
"	" 17	358	0	47	4	12	6	30 "	4
Barge	" 9	100	0	30	8	9	2	7 "	
"	" 11	82	0	28	5	9	4	250 tons	
"	" 12	100	0	34	0	9	6	450 "	
"	" 15	130	0	30	0	12	9	1000 "	

NAME OF VESSEL	CLASS	LENGTH		WIDTH		DEPTH	DISPLACEMENT (Tons)		ENGINES			BOILERS				RIG			NO. VES. OF THIS CLASS	
		Keel	Deck	Beam	Over Guards		Light	Loaded	No.	Cylinders	IHP	No.	Pres.	Heat Surf.	Grate Surf.	Type	Dia.	Pitch		
Newark	Pass. Ferry	268′	290′	42.5′	75.8′	18.8′	1136	1287	1	65″/12′	1200	2	56	8776	122	Side Wheel	25′–8″			S. P. Co.
Piedmont	“ “	257.1′	273′	39.5′	74.1′	15.6′	1212	1375	1	57″/14′	1385	2	60	5902	76	“ “	25′–8″		10	S. P. Co.
Santa Clara	“ “	273′	293′	42′	76′	17′	1580	1814	4	20″ & 40″ / 8′	2500	4	225	10,140	340	“ “	24′–0″			S. P. Co.
Melrose	Pass. & Frt. Ferry	273′	294′	43′	76.6′	17.9′	1344	1424	2	$22\frac{1}{2}''$–$38\frac{3}{4}''$ / 8′	1040	4	175	13,396	126	“ “	22′–7″		2	S. P. Co.
Navajo	River Steamer	219.8′	220′	42′	48′	8.9′	1033	1260	2	$22\frac{1}{2}''$–$38\frac{3}{4}''$ / 96″	1200	1	175	3710	61	Stern “	25′–2″		6	S. P. Co.
Solano	Car Transf.	407′	424′	65.5′	116.8′	17.4′	3900	4850	4	60″/11′	1600	8	90	15,784	448	Side “	30′–0″		3	S. P. Co.
San Pablo	Pass. Ferry	226′	238′	36′	64′	17′–6″		1584	1	38″–77″ / 66″	2500	2800B.H.P.				“ “	19′–9″		2	Santa Fe
	Car Floats	260′	272′–3″	39′	39′–8″	11′–6″	3-track Capacity	14–45′ cars											4	Santa Fe
San Jose	Pass. Ferry	175′–4″	200′	38′	58′	17′		1115	1	18″–27″–42″ / 28″	1200	2	200		45ea	Propeller	2–8′–4″	10.5′	2	Key Route
Fernwood	“ “	194′–3″	200′	38′	58′	19.2′		1160	2	20″–42″ / 28″	2000	2	200	4878 ea	140ea	“	2–9′–7″	12.5′	3	Key Route
Cazadero	“ “		231′	38′		17′		1682	1	56″/12′	1600	2	90			Side Wheel	26′		5	N.W. Pac.
Ukiah	Car Ferry		271′	41′–6″		14′–2″		2564	1	65″/12′	2200		50			“ “	27′		2	N.W. Pac.
E. T. Jeffry	Pass. Ferry		230′	42′	62′–6″	19′–6″		1150	2	20″–42″ / 28″	2000	4	200	10,000	234	Propeller	2–9′–9″	12′	1	Western Pacific
Telephone	“ “		201′–6″	31′–6″		8′–0″		600								Stern Wheel	25′–6″		1	Western Pacific
No. 1	Car Float	272′–0″	258′–4″	39′–0″	40′–10″	12′–6″	3-track Capacity	16 cars											2	Western Pacific



REAR ELEVATION
SIDE ELEVATION
FRONT ELEVATION
PLAN
GENERAL ARRANGEMENT
OF
APRONS AND HYDRAULIC HOIST
FOR
UPPER AND LOWER DECK LANDINGS
AT
SOUTH SIDE OF OAKLAND MOLE
FEB 1907
DRAWN AND TRACED BY M J M
MWD
DRAWING 367
SHEET 2
DRAWER 2809

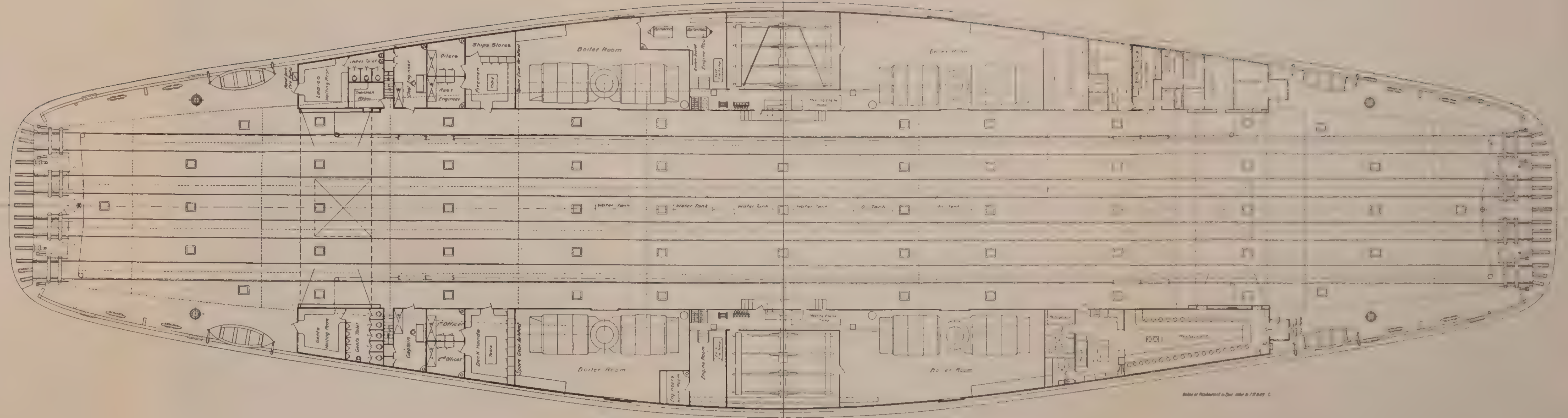

Saloon Deck
Main Deck.



Platform Deck
Cooks
Waiters
Firemen
Deckhands
Oiler
2nd Engineer
Condenser
Boiler Room
Restaurant
Stewards
SANTA CLARA
SOUTHERN PACIFIC
SANTA CLARA
General Dimensions
Moulded Beam 42'-0"
Moulded Depth 17'-0"

General Dimensions

Length over all	433'-4"
Length over Transoms	420'-0"
Width over Guards	116'-0"
Beam Moulded	66'-6"
Depth Moulded	19'-5"



DISCUSSION

Mr. A. H. Babcock,* Mem. A. I. E. E. (by letter), said if the author had been a little more specific in naming the location of the railroad whose floating equipment he was describing there would be no necessity for calling attention in particular terms to the ferry-steamer equipment of the various companies operating on San Francisco Bay. Mr. Babcock.

In comparison with the tabulation given on the last page of the author's paper, there is presented here a similar tabulation, showing the principal dimensions of the various types of vessels operated in the vicinity of San Francisco. The vessels listed therein are merely typical of their class.

In the concluding paragraph the author gives an idea of the equipment necessary to the railroad that maintains the greatest amount of floating equipment in New York harbor. Similar figures for San Francisco Harbor would be:

10 Passenger Ferryboats
2 Passenger and Vehicle Boats
6 Stern-wheel River Steamers
3 Car Transfer Vessels
1 Ocean-going Steamship
2 Tugs
6 Launches
2 Car Floats (one self-propelled)
3 Pile Drivers
3 Dredgers
4 Mud Scows.

The dredgers are all of the suction type.

The author names the Hudson River ferryboat as the highest development of its type, and gives the dimensions: 210 ft. long, displacement of approximately 1000 tons, capacity for 2500 passengers, motive power 900 i.hp., and speed of 10 knots. The tabulation shows for the vessels on San Francisco Bay lengths up to within a few feet of 300, displacements from 1100 to 1800 tons; the larger passenger vessels carry life-preservers for 3500 passengers; the i. hp. ranges from 1200 to 2500. Many of the vessels operate at a schedule speed of very approximately 16.5 knots.

The author calls attention to the methods for the loading and discharging of passengers and vehicles on the New York ferryboats, which are utterly incomprehensible to one who is accustomed to the methods ordinarily in use in San Francisco Bay, and who is disposed to observe the methods used in New York harbor with some amusement. On the west coast the cost of a single typical ferry slip with one half of the dolphin on each side will be $80,000, and the cost of the car ferry slips, $245,000; the side aprons for the handling of passengers cost approximately $14,500 per slip. Space does not permit a complete analysis of such structures as

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Mr. Babcock. the aprons at Port Costa and Benicia, where transcontinental trains are ferried across a river. The cost would mean little, because of local conditions that make very expensive piling necessary.

The ferryboats as operated today are the logical developments of a traffic that originated in the travel from San Francisco to the gold diggings, that is to say, up the various rivers. The vessels at that time were of the walking-beam type with large slow-speed wheels and very low boiler pressures. In those days there was no settlement on the east side of the bay to make necessary the swift, large, double-end boats now operated. When these were first developed they were merely modifications of the river steamers. One of the original vessels is now in service; her length is 225 ft., loaded displacements 697 tons, i. hp. 250. Step by step, as conditions changed, the dimensions of the vessels were increased, without, however, changing materially their general characteristics, until the first double-ended propeller boat was built about seventeen years ago. Owing to the limited draft of this vessel, made necessary by a shoal over which she was obliged to operate, it cannot be said she is a satisfactory vessel for ferryboat service, and it is probably well within the facts to state that all of the propeller boats now operating in this passenger service are satisfactory in inverse proportion to their over-all dimensions. For these reasons the latest developments are steel hulled, similar in shape to the double-end type originally developed, but equipped with horizontal inclined engines, one or two on each paddle wheel, according to the individuality of the designing engineer.

Ice is never known in San Francisco harbor, consequently one of the chief advantages of a propeller-driven ferryboat disappears, as far as this locality is concerned.

Some persons who have traveled a great deal and who have seen different types of ferry equipment in different parts of the world have expressed themselves to the effect that "the highest development of the type" is to be found somewhere else than in the neighborhood of New York.

Paper No. 93

ELECTRIC MOTIVE POWER IN THE OPERATION OF RAILROADS.

By

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San Francisco, Calif., U. S. A.

In considering the question of electric motive power versus the use of steam locomotives, the probability of the electric motive power being proper for adoption is evidently greater when a new railroad is to be equipped than if the question pertains to an existing railroad, and lies between retaining the steam locomotives or purchasing new electric locomotives in addition to the other expenses of equipping the road for electrical operation.

This question is especially important when the existing railroad is an extensive suburban system, with steam locomotives and cars of special adaptation to the service and not suitable for general use on a steam-operated main line, and which suburban system is giving satisfactory returns on the investment.

In such a case the change to electrical operation, with the probability of cost being much in excess of the estimates and the possibility of increase of traffic being much less than predicted, together with the practical loss of the original rolling stock may transform a satisfactory, remunerative property into a heavily losing investment for a disastrously long period.

That is, the probabilities of the propriety of electrical operation are:

(1) Greatest on a new main line railroad;

(2) Next greatest on an existing main line railroad when the equipment, other than motive power equipment, will not be changed;

(3) And next greatest on a portion, that is on one or more operating divisions of an existing main line railroad, when the equipment, other than motive power equipment, will not be changed;

(4) And least on a railroad when electrification involves scrapping or nearly corresponding salvage value of existing equipment.

When these matters are under consideration, the amount of risk to investors depends on whether the one making the decision is in charge of matters that he does understand and also of matters that he does not understand, the decision being either a matter of fiat or otherwise, as the case may be.

The inconveniences of electrical operation of part of a main line, a division or more, have been so fully discussed as to require no more than mention, as for instance, the certainty of increased investment for motive power of both classes over that required for operation of the entire road either by steam or by electric locomotives.

When this partial method is correctly adopted, the evident disadvantages of the two kinds of motive power must have been more than balanced by the saving due to the electrical operation of the parts of the road so operated.

The question of whether or not to adopt electric motive power on a portion, for instance on an operating division, of a main line elsewhere operated by steam locomotives is especially likely to be taken under advisement in reference to a mountain operating division having a steep grade system of considerable length, the electric operation at first glance appearing particularly attractive on such a piece of railroad.

Evidently such a railroad if already built with a double track is more conveniently operated either with electric locomotives or with steam locomotives, than if built with only a single main line track.

The opinion that is sometimes entertained, however, that in cases where a single-track road is already overburdened with traffic as handled by steam locomotives, the substitution of electric locomotives will materially postpone the expenditure necessary for double tracking the road is not always correct, excepting with the condition that an unusual and, per-

haps properly termed, unreasonable and impracticable amount of electric power is available at a cost that can be properly contemplated.

The reason for this condition is that on a single-track mountain railroad operating division with a steep grade system and having a considerable number of daily passenger trains throughout the year, the time of passage of these trains over the mountain division cannot be materially modified, owing to necessary business adjustment of times of departure from and arrival at important terminals. And with a considerable freight traffic at all times, and perhaps several times the average freight traffic at certain seasons of the year, it is necessary to move a number of freight trains of maximum practicable size one after the other, and as near as practicable to each other, up the steep grade, at such periods of the twenty-four-hour day as will least interfere with the passenger train movements.

This is accomplished without difficulty with the use of steam locomotives, which, per varying necessities of traffic volume, can be used on any operating division.

When such mountain operating division is operated electrically, however, not only must the adequate number of electric locomotives be on hand for meeting these traffic conditions, but the amount of electric power available must correspond to the special traffic requirements.

The following table gives an approximate statement of electric power required on mountain grades under the conditions and approximate assumptions stated.

It will be noticed from the following tabulation that on 2.2% up-grade there will be required about the following power-house delivery into transmission line of ordinary length by a hydraulic plant in the general vicinity of the railroad.

Passenger train of 250 tons exclusive of locomotives	1600 kilowatts
Passenger train of 400 tons exclusive of locomotives	2300 kilowatts
Freight train of 2000 tons exclusive of locomotives	4900 kilowatts

By the necessary method of operation of a single-track road heretofore outlined, the maximum power-house output for freight trains only, at certain seasons of the year, might reach about

Speed Miles per hour	Grade rate Per cent	Train resistance including gravity Pounds per ton	Trains				Hydraulic power-house output Axle to power-house as 51 to 70	
			Number of locomotives	Weight of locomotives Tons	Train Tons	Trains and locomotives Tons	Kilowatts per ton	Kilowatts per train
				Passenger Trains.				
30	1.0	21.0	1	100	400	500	2.539	1,270
30	1.0	21.0	1	100	250	350	2.539	889
30	1.5	41.0	1	100	400	500	3.359	1,680
30	1.5	41.0	1	100	250	350	3.359	1,176
30	1.8	47.0	1	100	400	500	3.850	1,925
30	1.8	47.0	1	100	250	350	3.850	1,348
30	2.0	51.0	1	100	400	500	4.178	2,089
30	2.0	51.0	1	100	250	350	4.178	1,462
30	2.1	53.0	1	100	400	500	4.342	2,171
30	2.1	53.0	1	100	250	350	4.342	1,520
30	2.2	55.0	1	100	400	500	4.505	2,253
30	2.2	55.0	1	100	250	350	4.505	1,577
				Freight Trains.				
15	1.0	25.8	2	200	2,000	2,200	1.057	2,325
15	1.5	35.8	3	300	2,000	2,300	1.466	3,372
15	1.8	41.8	4	400	2,000	2,400	1.712	4,109
15	2.0	45.8	[illegible]	400	2,000	2,400	1.876	4,502
15	2.1	47.8	4	400	2,000	2,400	1.958	4,699
15	2.2	49.8	4	400	2,000	2,400	2.040	4,896

40,000 kilowatts, with perhaps 8000 kilowatts for passenger trains, being about 48,000 kilowatts in all, and possibly more; while for much of the year the requirements would be very considerably less, making an undesirable method of power production as to cost of operation and of installation.

In general, a transportation company will find it impolitic to attempt to equalize power production and fluctuating consumption on so large a scale by entering the market and selling power to suitable consumers in competition with power producing companies regularly in the business of supplying the market.

This results in the cost of power to a railroad company for operating a mountain division being, in general, equal to the entire cost of operating the power house or houses and their related plants plus the entire fixed charges, without very material variation in this cost on account of variations in amount of traffic as between seasons of the year or as between the several years.

That is, the cost of power under these conditions has no direct relation to the actual power expenditure for conducting transportation, and in a way is analogous to the fixed charges pertaining to power-plant installation, as well as to the fixed charges pertaining to the cost of the railroad itself, which fixed charges are constant, regardless of traffic fluctuations.

On a similar mountain division having 2.2% grade and with a double track, the conditions would evidently be much more favorable, and the maximum power-house output for freight trains only at the heaviest traffic period might be no more than 10,000 kilowatts, with perhaps 8000 kilowatts for passenger trains, being 18,000 kilowatts in all; while for much of the year the requirements would be considerably less.

In general, the cost of double tracking a mountain division will be so great that it should not be done until absolutely necessary, especially in view of possible failure of traffic to increase or even remain constant, on account, for instance, of the construction of competitive lines, entered into judiciously or otherwise.

Evidently on light grade railroads the question of amount of installation of power plant versus fluctuations of traffic is less serious.

The reduction in the necessary production of electric energy by the returning to the line of energy produced by the control of descending trains on a mountain division, electrically operated, might be worth the expense of installation of the necessary appliances as effecting some fuel saving in a steam-power electric-generating station; but when the electric energy is developed in a water-power station, the power saving would be of doubtful value, and in particular because, as heretofore outlined, the cost of power so produced is not per kilowatt hour or any usual function, but is essentially so much per year, regardless of any ordinary fluctuations of power requirements.

The increasing cost of fuel for steam locomotives or for steam electric-generating plant tends to hasten the time when railroads will be operated by electric power generated by hydraulic plants, particularly on mountain grades.

Presumably much more would have been accomplished in this direction if the National laws and regulations had been so modified as to give to railroad companies the necessary confidence to enable them to make the very large investment required.

Some large water-power locations made by railroad corporations with a view to their development and utilization for mountain railroad operation have, after considerable preliminary expenditure, been abandoned when it was found that after the installation expenditure, the right to continue the operation would depend entirely on the several successive Secretaries of the Interior.

This condition is well understood and preliminary steps have been taken at times to correct it, but without satisfactory results in the way of legislation.

DISCUSSION

Mr. Hood.

Mr. William Hood, to the questions:

(a) As long as large power companies are in operation and parallel the railways, is it not possible for the railways to purchase power from them?

(b) What makes the great difference between the load on a single- and double-track system as stated in the paper?

(c) In figuring the consumption of power was any account taken of the regeneration of power?

Answered: Mr. Hood.

(a) That the first thing that would occur to one was the purchase of power, but that never yet had they been able to get a power company to give an unqualified answer that it could furnish the requisite amount of power at any time. If the power company is forced to install new equipment to handle the railroad load it wants the railroad company to stand the expense.

(b) That the great difference is on account of the better distribution of freight traffic on the double-track line.

(c) That the regeneration of power had not been considered in the estimate.

Paper No. 94

ELECTRIC MOTIVE POWER IN THE OPERATION OF RAILROADS.

By

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DEVELOPMENT AND PRESENT STATUS.

General.

The evolution of electric traction as applied to the operation of standard railways has advanced along two distinct lines of development: In one line there has been a normal development in progressive steps, beginning with the earliest successful commercial application of the new method of motive power to light surface railways in Richmond, Va. (1888), culminating in the heavy high-speed motor car trains of today; while in the other line the many faults and disabilities of steam operation in subways, tunnels and large passenger terminals created the need for some better form of motive power capable of performing the same functions and forced the very rapid development of an electric locomotive, which, like Minerva, sprang full grown into existence. In both lines the first commercially practicable installations were completed almost simultaneously, and although originating in widely separated classes of service and for very different reasons, have since steadily converged to a common goal.

Light Surface Railways.

A very rapid development and extension followed the successful issue of the epochal installation at Richmond, Va., by F. J. Sprague, which, of the many early experiments, has alone survived the test of time. The length of the light city and suburban routes then in existence was usually within the economic radius of the earlier power stations, which supplied low tension continuous current direct to an overhead contact wire,

but it was soon evident that the valuable possibilities afforded by higher speed and larger cars were severely limited and restricted by the relatively short distances over which the current could be economically transmitted, thus tending to retard further progress.

Interurban Railways.

These limitations were soon overpassed and the next great step in advance was made possible by Tesla's invention of the polyphase system, in which are retained the economical features of long distance, high-tension transmission, and which converts high-tension alternating currents into low-tension continuous currents by transformers and rotary converters installed in local sub-stations located at intervals along the line of route. The earliest application of this system to interurban traffic was made in 1890 by the Twin City Rapid Transit Company between St. Paul and Minneapolis. Mr. E. P. Burch in his valuable compendium "Electric Traction for Railroad Trains" (1911), in referring to this stage of development, notes: "In the whole history of transportation no development has been more wonderful and important than that of the electric interurban railways". For convenience, all railways of this class may be considered to include those intermediate between the light surface street railways and the "so-called" steam railroads, although no precise lines of demarcation can be established at either limit. Many such lines fulfill all the requirements and functions of a high class steam railroad, but in general the service is of a lighter character and more particularly designed for passenger traffic. The number of lines of this character in existence today in all parts of the world almost defies enumeration, and their economic value is very large.

Subway and Elevated Lines.

Railways so classified properly form a sub-group under the general head of Interurban Railways. The adoption of electric traction in such service was the logical result of the wider field of operation afforded by the success of Tesla's polyphase system. The more or less complete elimination of smoke, sparks, cinders, heat and gases permitted by electric traction peculiarly adapts it to urban conditions, more particularly in subways in which additional and even more important advan-

tages are gained in the greater safety and increased track capacity.

In the earlier stages of development, motor cars were operated singly or in light trains with a motor car hauling one or more "trail cars", of which the Intramural Railway at the World's Fair in Chicago, 1893, was perhaps the earliest example, but it was not until after the invention of the first practicable system of multiple unit control by F. J. Sprague, and its adoption by the West End Elevated Railroad in Chicago in 1898, that the full utilization of the inherent economy and advantages of electric traction in motor car trains became possible.

Steam Railroads.

It is unfortunate that no distinctive and precise appellation for converted railroads of this class has yet been adopted, nor is it easy to suggest one, as they do not possess a single distinctive feature of operation which is not shared in common by the lighter lines. The somewhat awkward term of "electrified railroads" is frequently applied to railroads of the class generally operated by steam locomotives in the heavier and higher class of transportation service, but a better term is very much needed. All things considered, the term "Standard Railways" adopted by Mr. E. P. Burch, seems most satisfactory. The distinction between converted steam railroads and new electric railroads of the same class will probably disappear as more new railways for electric operation are constructed. The history of the development in this field is virtually a repetition of that of the lighter lines, beginning a little later in the order of time and ultimately reaching a more advanced stage of progress through the same series of steps in a higher order of service.

A recital of the earlier experiments by Tesla, Villard, Sprague and others may be omitted as lying outside the scope of this paper, but it may be of interest to note that the first serious consideration of the application of electric traction to heavy railroad service was undertaken by Mr. Henry Villard, who appointed a commission early in 1892, of which the writer was a member, to investigate and report on the feasibility of electrically equipping and operating the main line of the North-

ern Pacific Railroad. This commission visited the works of all prominent electrical manufacturers in the United States in existence at that time, but made no substantial progress apart from the completion of a schedule of service requirements and general specifications for an electric locomotive substantially as constructed in the course of the following year by the North American Company under the direction of its President, Mr. Henry Villard. The great advance since that date may be best illustrated by referring to a design of locomotive then presented by Mr. Thomas A. Edison, which embraced an engine with two four-wheel trucks with centrally mounted D. C. motors transmitting power to the driving wheels by an arrangement of rope drives and belt tighteners. Electric current was to be taken from an unprotected third rail located in the center of the track, at 30 volts.

Light Passenger Service.

The subsequent evolution following these crude beginnings at first separated into two distinct lines of progress, as before noted; in one of which the primitive type of motor cars hauling one or more trailers was simply substituted for the steam locomotive previously used, from which the powerful high-speed motor car trains of today have grown. The pioneer installation of this kind was made on the Nantasket Beach Branch of the New York, New Haven & Hartford Railroad Company in 1895, which was only seven miles in length (11.26 km.).

Tunnel Lines.

The necessity for some form of motive power better adapted to conditions of tunnel operation, and free from the many objections attending the use of steam engines in similar service, forced the almost simultaneous development of an electric locomotive of sufficient tractive and horse power to afford a satisfactory and efficient substitute for the steam engine then in use. The first commercially practical engines of this kind were operated by the Baltimore & Ohio Railroad through its Baltimore Tunnel in 1905; only a few months later than the initiation of electric service on the Nantasket Beach line above mentioned. The five electric engines installed were of 1000 h.p. each and are still in active service. The great gain in

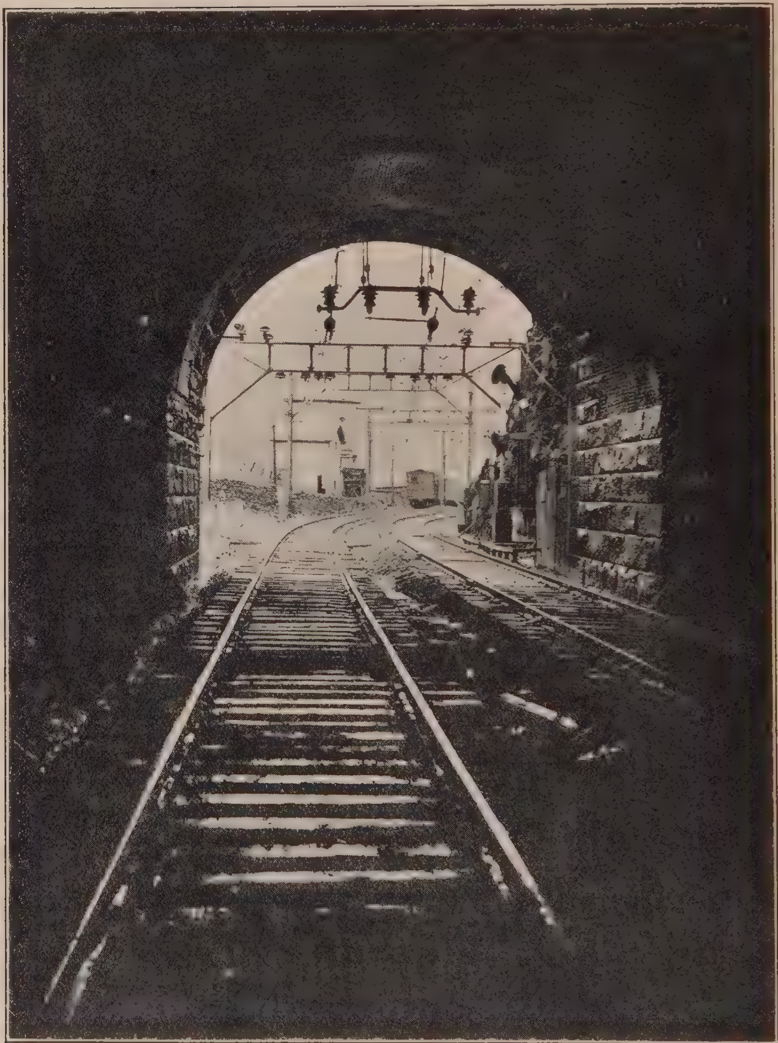


Fig. 1. Boston & Maine Railroad, Hoosac Tunnel. Tunnel and approach construction.

track capacity, safety and other benefits was immediately apparent and the present list of tunnel sections so operated is a very long one, including such notable examples as the Baltimore Tunnel, B. & O. R. R., 1905; Woodlawn Tunnel, N. Y. C. & H. R. R., 1907; Sarnia Tunnel, Grand Trunk Railway, 1908; Cascade Tunnel, Great Northern Railway, 1909; Detroit River Tunnel, 1910; Hoosac Tunnel, B. & M. R. R., 1911,—all in the United States, and the longer Simplon, Lötschberg, Mont Cenis and Arlberg Tunnels in Europe. The five-mile tunnel of the Canadian Pacific at Rogers Pass, B. C., will also be electrically operated upon its expected completion in 1916. The operation of mountain sections of high resistance properly demands a classification of its own as the factors to be taken into consideration in this class of service are quite distinct from those influencing a choice of motive power for tunnel operation, but tunnels and mountain lines are usually so inseparably associated that with one or two possible exceptions there are no installations of this kind which have not primarily been influenced by the existence of important tunnels.

Railroad Terminals.

Next in the order of time and importance, electric traction was adopted in large terminals, to which it is peculiarly well adapted. The high value of real estate and the frequent tunnels, multiple track levels and many other advantages of the new form of motive power, forced its adoption even in advance of the time when such applications had become practical and available.

By an Act of Legislature of the State of New York (May 7, 1903) the New York Central and the New Haven systems were required to operate their trains within specified limits in the City of New York on or before July 1, 1908, by some form of "motive power other than steam which does not involve combustion in the motors themselves". It was the primary purpose of the legislation to insure greater safety in the operation of the well known Park Avenue tunnel, but the practical effect was to force the conversion to electric traction of a four-tracked main line section twelve miles in length, including Grand Central Terminal in New York City. The magnitude, complexity and high traffic density of this great passenger ter-

minal made necessary the solution of many new and formidable problems on a much higher plane of operation than had been previously attempted, which was successfully accomplished by the engineers of the New York Central & Hudson River Railroad.

Only less remarkable, because less novel, is the Pennsylvania's great passenger terminal in New York City, which was completed two years later and operated by electric power from the beginning. Other railroad terminals have been electrified in this country and abroad, some of which antedate the two most prominent examples already cited. The latest addition to the list is that of the Mt. Royal Tunnel and Terminal of the Canadian Northern at Montreal, Can., now nearing completion.

The public interest in this phase of electric traction is very keen and has forced upon the railways the consideration of similar installations in many of our great cities. Of all such projects, the most important is the proposed electrification of all railroads within the city limits of Chicago, which is now under consideration by a commission especially appointed to study and report upon its feasibility and cost. This great project includes 4501 miles (7242 km.) of single track in two zones, of which 2819 miles (4536 km.) is included within the inner zone or city limits. The great capital expenditures required, together with inadequate returns upon the invested capital, tend to retard progress on all such projects, and under present conditions of failing income due to the prevailing commercial depression and to the blighting repression of the Interstate Commerce Commission, no material advance may be expected in the immediate future.

Switching Yards.

Electric switching was initiated very early and has now reached an advanced stage, best represented in the Mott Haven Yard of the New York Central & Hudson River Railroad, the Sunnyside Yard of the Pennsylvania and the Oak Point and Harlem River Yards of the New York, New Haven and Hartford Railroad,—all within the city limits of New York. The two largest yards of the New Haven Road include 60 miles (96.5 km.) of trackage, transfer float bridges, freight stations and general facilities of all kinds for handling the immense

volume of freight traffic of the New Haven system to and from New York City.

Long Distance Traffic.

It is impossible to preserve absolute continuity in attempting to trace the progressive development of electric traction in all of its applications, as such developments must necessarily overlap and merge in ever increasing degree until the entire

Fig. 2. New York, New Haven & Hartford Railroad. Harlem River Branch, Oak Point Yard. Switch engine at work. Single-phase.

field of railroad service is covered, including passenger and freight traffic; yard and terminal switching, and the movement of baggage, mail and express matter in the heaviest class of long distance trunk line service.

The Long Island Railroad was the first steam road to equip its lines for passenger travel on an extensive scale (1905), and the Spokane & Inland Empire, which while not originally a steam road, was the first to attempt long distance heavy freight traffic in 1906, and now operates 216 route miles (347.5 km.) in

its electrified system. Later and more advanced examples of railroad electrification in this class in the United States are afforded by the New York, Westchester & Boston; Norfolk & Western; Baltimore & Ohio and Chicago, Milwaukee & Puget Sound.

European railways are more difficult to classify as their service is usually of a lighter character and the electrification has been more often influenced by terminal and suburban con-

Fig. 3. Denver & Rio Grande Ry., Salt Lake Division. Mountain operation on 4% grade. Grades reduced to 2% in 1913.

ditions, or by the existence of high grade tunnel sections of line, but such important examples as the London, Brighton & South Coast Railway in England; the Midi Railway of France; the Dessau-Bitterfeld and Lauban-Konigszelt electrifications of Germany and the Valtelina Railway of Italy are typical railways of the same general class.

Of the examples cited, the New York, Westchester & Boston of the New Haven system presents the highest type of development in passenger service, for which it was primarily designed;

this road having been electrically operated from the date of its completion.

The installation by the Butte, Anaconda & Pacific, Norfolk & Western and the Chicago, Milwaukee & Puget Sound afford modern and interesting examples of the application of electric traction to heavy freight traffic; which in all three cases was chiefly influenced by the existence of sections of heavy mountain grades. The Butte, Anaconda & Pacific is an

Fig. 4. New York, New Haven & Hartford Railroad, Harlem River Branch. Six-track main line tangent construction.

ore-carrying road operating between the mines and smelters of the Anaconda Mining Company at Butte and Anaconda, and has sections of high grades at both terminals. A heavy coal and ore traffic is conducted in trains of fifty loaded cars of 3400 tons (3085 tonnes). The electrification of the entire mileage is nearly complete, comprising thirty miles (48.3 km.) of main route or ninety miles (144.9 km.) of total trackage. Electric operation has been recently initiated.

A later mountain electrification, still under construction, is that of the Norfolk & Western between Vivian and Bluefield, West Va., including about thirty route miles (48.3 km.) or seventy-five miles (120.7 km.) of total track. This is a section of high grade over which it is proposed to conduct a heavy coal traffic on 2% maximum grades in trains of 3250 tons (2768 tonnes).

The latest and most interesting project is that of the Chi-

Fig. 5. New York, New Haven & Hartford Railroad, Harlem River Branch. Freight engine and train—single-phase. Six-track main line tangent construction.

cago Milwaukee & Puget Sound, which has quite recently announced its decision to equip for electric operation four engine districts of its main line from Harlowton, Mont., to Avery, Idaho,—a distance of 440 miles (708 km.) of which the first engine district between Deer Lodge and Three Forks, 113 miles in length (182 km.), will immediately be placed under construction. The total section includes several long mountain inclines on the Belt, Rocky Mountain and Bitter Root Moun-

tain ranges, with maximum grades of 2% which it is proposed to operate with trains of 2500 tons (2268.6 tonnes). While the main line is single-tracked only and the traffic density is relatively low, in point of combined train weights and length of route, this electrification will mark the point of furthest advance in this particular field.

Heavy Trunk Lines.

There is as yet little to be written under this head, but

Fig. 6. New York, New Haven & Hartford Railroad, Harlem River Branch. Multiple-unit passenger train, six-track main line tangent construction.

broad foundations have been laid and the outlines of the future superstructure have already taken shape. The great installations of the Pennsylvania and the New York Central & Hudson River Railroad Companies at New York City have not yet extended beyond the terminal and suburban zones for the transportation of passengers, baggage, mail and express; nor does the service include any part of the enormous volume of freight traffic within these zones, but a large proportion of the expen-

ditures already incurred will become available and applicable to freight traffic with more extended operating limits and when electric operation is made general and homogeneous. The electrification of the Pennsylvania lines in and about Philadelphia, which has been already begun between Philadelphia and Paoli, 20 miles (32.2 km.), is a long step in this direction, and foreshadows continuous electric operation between New York and Washington at no distant date. The greatest progress in extended homogeneous trunk line operation has been attained by the New York, New Haven & Hartford Railroad, which has completed the equipment of its four- and six-track main routes to New Haven, Conn., within the past year and now operates by electricity trains of all classes between New York and New Haven, 73 miles (117.5 km.). All steam engines will be eliminated when the full quota of electric engines and cars has been received. The route and track mileage of the electric zone operated by the New Haven Road within these limits, including joint trackage and controlled lines, is 112 route miles (180 km.) and 633 miles (1019 km.) of single track of all descriptions.

A comprehensive review of the progress to date and the present status of standard railway electrification is best afforded by the tabulated data recently compiled by Mr. Edward P. Burch of Minneapolis, appended hereto, which is believed to afford the latest and most reliable list now available.

ADAPTATION TO TRAFFIC REQUIREMENTS.

Advantages.

The adaptation of electric traction to the requirements of railway service in many cases seems almost perfect, as many of the objections and limitations of the older steam service are avoided and the advantages are so numerous and diversified as to permit only a brief mention of the more salient features. The relief from annoyances and losses due to smoke, cinders, hot gases and the reduction of fire risks is general and of high commercial value. In tunnels and terminals the value of these improved conditions is increased and further augmented by additional gains.

L. C. Winship, Electrical Superintendent of the Boston &

Maine Railroad Company, in a recent article on the electric operation of the Hoosac Tunnel, (4¾ miles, 7.7 km.) notes benefits arising from the electric operation of this tunnel since its completion in 1911 as follows: Maximum train tonnage ratings increased from 1300 to 3200 tons (1179-2904) tonnes); track capacity doubled; overtime wages decreased; better rail adhesion; unobscured signals; no asphyxiation of engine and train crews; reduced track maintenance; life of rail and fastenings increased from 3½ to 4 years to 10 to 12 years; drier and cooler air and greater comfort to passengers and employees.

The same advantages are gained at electrically operated passenger terminals in more or less degree, together with other advantages of great commercial value, more particularly by the better utilization of costly terminal real estate and augmented capacity permitted by multiple track levels and improved conditions of operation.

In large terminals and switching yards, electric switching service is peculiarly convenient and profitable. The fuel saving is maximum and the engines are much better adapted to the service conditions and requirements. J. A. Droege, General Superintendent of the New Haven Road, advises that the use of such engines permits actual continuous operation, particularly in eight-hour yards, and cites a case in which one engine worked continuously for thirty days in switching service without delays for repairs or other attention.

In passenger service the higher rates of acceleration permit faster train schedules; terminal delays and terminal switching are reduced; also the train mile cost. Similar gains are made in every branch of service, to which may be added the advantage of higher train speeds, greater engine horse power and increased engine mileage,—all of which are features of high commercial value. "Three round trips between New York and Bridgeport, Conn., can be made in the same time with electric freight engines as are required for two round trips with steam engines".—J. A. Droege, General Supt., N. Y., N. H. & H. R. R.

At engine terminals the necessity for coal and water stations, ash pits and turntables is eliminated and roundhouse expenses are much reduced. Much less time is lost in shop-

ping engines as the repairs are less in amount and the necessity for general overhauling at intervals of 12 to 15 months is avoided.

The design of electric engines permits ready substitutions of damaged parts with minimum detention in shops. The uniform radial torque of motors contrasts most favorably with the uneven "moments" of crank pins. The gain in effective "adhesion" is about 20% ("Locomotive Operation", Henderson, page 206. The electric engine must be credited with a further unique and valuable characteristic, in that its horse power increases with lower temperatures, thus compensating increased friction and radiation losses at such temperatures. Also, higher rates of acceleration permit faster train schedules; machinery friction is reduced and track capacity is increased; time and money are saved at engine terminal in "firing up" and drawing fires; charges for engine fuel and repairs are heavily reduced;—all of which are considerations of great value.

Large savings are also possible in charges under head of "Maintenance of Track and Structures", which at least partially compensate for the additional cost of maintaining the necessary transmission and distributing systems.

The life of rails, ties and bridges and other structures forming part of the track equipment may be considerably increased.

Fire hazards from locomotive sparks and cinders are eliminated; the painting on bridges and buildings needs less frequent renewals and the recurrent cost of cleaning rock ballast of cinders is avoided.

A cheap and convenient source of power is afforded which is almost universally available for all purposes, including train lighting and heating; yard, station and other lighting; energizing track circuits and other signaling requirements; operating pumping stations, drawbridges, transfer bridges, turntables, shop tools and machinery of all kinds.

The list of benefits and advantages is a long one and if reduced to equivalent values in dollars and cents would afford substantial credits to railway electrification, but there are also other charges to be made to the debit side of the account, which too often result in an unfavorable balance.

LIMITATIONS.

Variable Speed.

The inability of the electric engine to flexibly utilize its available horse power by inversely varying speed and tractive effort is a severe handicap under some conditions, as later explained.

Diversity of Type.

Another factor which undoubtedly exercises a deterrent effect upon the more rapid adoption of electric traction is the number and diversity of the types now under trial, together with the yet unsettled opinions of the specialists in this field. Reference to the appended list will indicate that the progress in Europe has been principally confined to single-phase and three-phase systems, while in England and the United States the struggle for supremacy has been almost wholly between the single-phase and direct current systems. It was both inevitable and desirable that evolution should have simultaneously progressed along many different lines, as an exploration of so broad a field was necessarily antecedent to the adoption of a final type through a process of the "survival of the fittest". In late years the convergent tendency of all systems to a common type is strongly marked.

The earlier direct-current 600-volt system has progressed in successive steps to 1200, 2400 and 3000 volts, with even higher stages already foreshadowed, but with rising voltage has been forced to abandon the earlier third rail conductors in favor of the single-phase high tension overhead distribution system, while on the other hand the single-phase systems show a strong tendency toward the adoption of direct current motors.

Three-phase installations have graduated into the split-phase system of the Norfolk & Western, in which single-phase transmission and distribution are joined with three-phase engine motors, and the latest development of the mercury converter in an experimental engine now under trial bids fair to reconcile all differences of opinion by combining the chief merits of all systems into one. The writer cannot refrain from betraying his inner convictions at this point by remarking that the single-phase system is the only one which permits the simultaneous and independent operation on the same track of

single-phase, three-phase and direct current locomotives, all taking current from the same overhead wire.

Restricted Radius of Operation.

Electric traction also labors under disabilities of restricted radius of operation, which limits commercial efficiency. This is a temporary disadvantage, however, and grows less as the zone limits are enlarged. Also, the greater freedom and flexibility of operation within the zone limits apply in compensa-

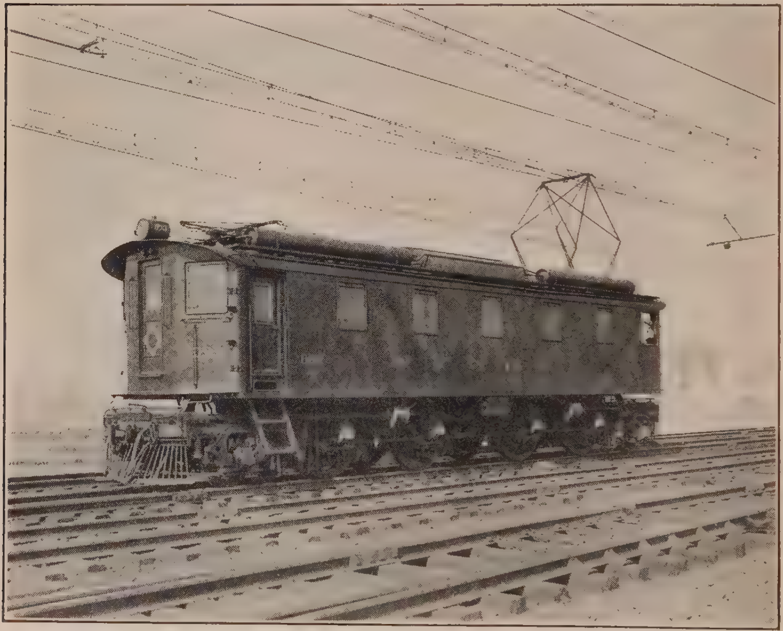


Fig. 7. New York, New Haven & Hartford Railroad. Electric engine—single-phase. Double articulated truck type, 8-motor, 1360 h. p.

tion, as electric engines are less dependent upon local engine facilities and can be used with much more advantage on detached or outlying service; at intermediate yards; on "shuttle" runs and in assistant engine service on relatively short inclines.

Complexity of System.

Among the penalties to be paid for each step in advance in all lines of development are the ever-growing complexity of systems and the higher degree of organization required for

operation. Electric traction in its highest form affords a striking example of this tendency, as the transfer of the fire-box and boiler from the locomotives to fixed locations along the line of route leads to the necessity for an intricate and highly developed system of inter-related and inter-dependent power stations, line equipment and locomotives requiring more highly specialized and better paid labor for its proper maintenance and operation.

Continuity of Service.

There is also a greater concentration of risk both in maintaining the physical continuity of service and in the relations of railways to organized labor. Regarding these aspects it may be said that train delays and interruptions to service are actually less frequent than before and that while greater dependence must be placed upon the operating organization, this must be accepted as incidental to progress in all of the applied arts. In the evolution of transportation from the two-wheeled cart to the electrically operated trains of the present day, each step has been attended by increasing inter-dependence between the parts and corresponding losses of freedom in the elementary units.

Induction and Electrolysis.

Induction may seriously impair telegraph and telephone service in adjacent circuits, and is more particularly incident to single-phase operation. Electrolysis may cause great damage to pipe systems, under-ground cables and all metal structures, but its effects are practically confined to direct-current operation. Induction can now be practically eliminated by special devices and methods. It is more difficult to eliminate electrolysis to the same degree, but more or less satisfactory means to this end have been devised.

Difficulties of Transition.

Among the minor difficulties should be noted those arising in the transition stage in changing from steam to electric power, more particularly those incident to train lighting and heating; mixed steam and electric operation; engine transfers; track signals; restricted interchangeability of engines and cars and other difficulties of adaptation. These difficulties are greatest in the earlier stage of the transition, but rapidly diminish in

both absolute and relative importance as the zone of electric operation is extended.

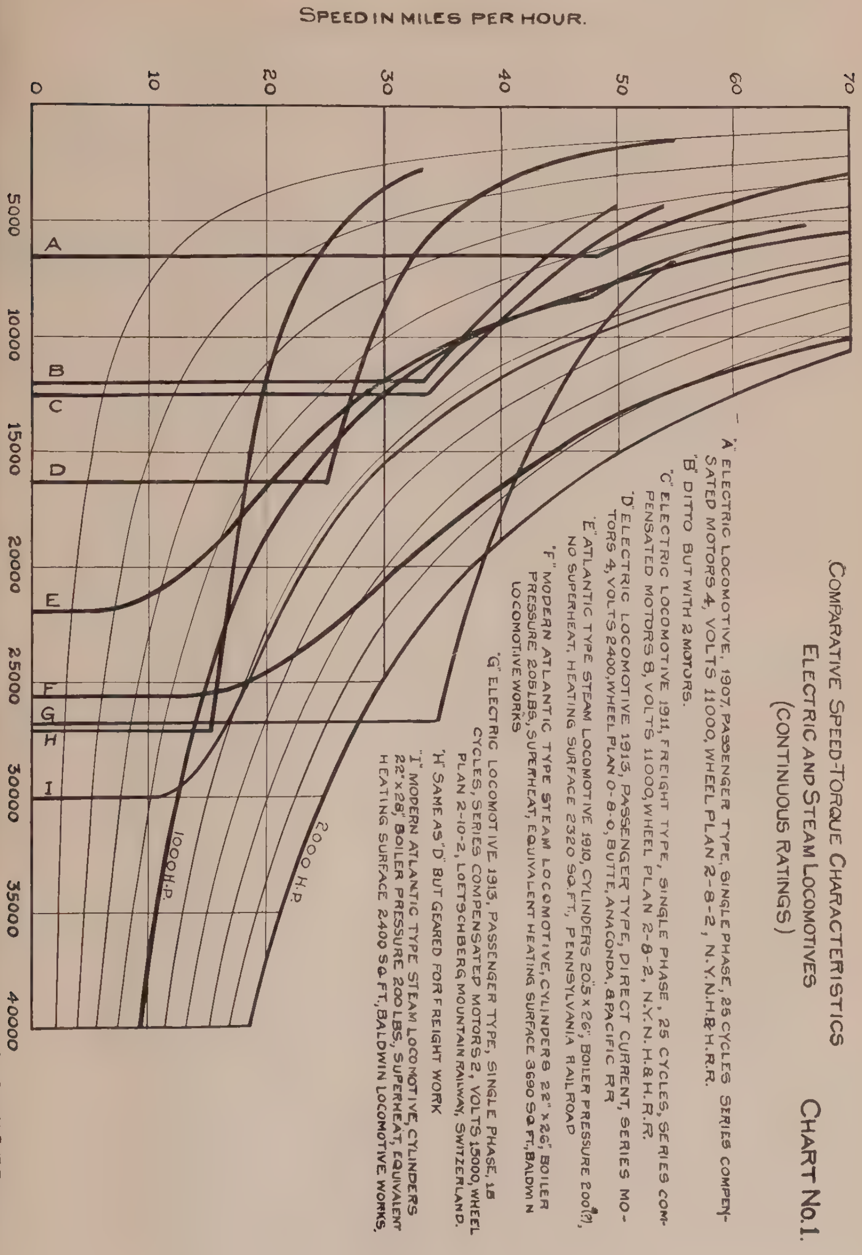
FUTURE POSSIBILITIES AND TENDENCIES.

The trend of future development in so new an art is difficult to forecast as it has as yet barely made a beginning in the vast field which it is destined to occupy. The problems incident to the movement of enormous volumes of long distance freight traffic have but recently begun to receive serious consideration, and in the next decade it is probable that the greatest development of electric traction will occur in this branch of railway service.

Speed-Torque Control.

A better utilization of the possibilities of the electric locomotive is probable, which in one important particular compares very unfavorably with the steam engine of the same horse power capacity, as it cannot effectively utilize its rated capacity throughout the same wide range of variable speed and tractive effort, which has the effect of greatly limiting its field of usefulness. This disability is only partially mitigated by various methods of extending the operating range by the use of various systems of potential and field speed control or of pole-changing devices to obtain the desired effect. The radical difference in the speed-torque characteristics of steam and electric engines will be readily understood by referring to the accompanying charts (Nos. 1 and 2) which indicate the necessity for closely designing electric engines for the service to which they will be assigned, as they cannot be operated above the critical speeds corresponding to their horse power ratings without serious reductions of horse power capacity; nor can their effective adhesion be continuously utilized at lower speeds without exceeding safe temperature limits, or, as an alternative, of accepting severe penalties at the other end of the scale. Of the different types of motors most available for railroad service, the single-phase motor most nearly attains variable speed with equal horse power.

A fuller discussion of the characteristics of single-phase, three-phase and continuous current motors is outside of the proper scope of this paper, as it is only sought to show the rela-


COMPARATIVE SPEED-TORQUE CHARACTERISTICS
ELECTRIC AND STEAM LOCOMOTIVES
(CONTINUOUS RATINGS)
CHART No. 1.
"A" ELECTRIC LOCOMOTIVE, 1907, PASSENGER TYPE, SINGLE PHASE, 25 CYCLES SERIES COMPENSATED MOTORS 4, VOLTS 11000, WHEEL PLAN 2-8-2, N.Y.N.H.&H.R.R.
"B" DITTO BUT WITH 2 MOTORS.
"C" ELECTRIC LOCOMOTIVE 1911, FREIGHT TYPE, SINGLE PHASE, 25 CYCLES, SERIES COMPENSATED MOTORS 8, VOLTS 11000, WHEEL PLAN 2-8-2, N.Y.N.H.&H.R.R.
"D" ELECTRIC LOCOMOTIVE 1913, PASSENGER TYPE, DIRECT CURRENT, SERIES MOTORS 4, VOLTS 2400, WHEEL PLAN 0-8-0, BUTTE, ANACONDA, & PACIFIC RR
"E" ATLANTIC TYPE STEAM LOCOMOTIVE 1910, CYLINDERS 20.5 x 26", BOILER PRESSURE 200(?), NO SUPERHEAT, HEATING SURFACE 2320 SQ.FT., PENNSYLVANIA RAILROAD
"F" MODERN ATLANTIC TYPE STEAM LOCOMOTIVE, CYLINDERS 22" x 26", BOILER PRESSURE 205 LBS., SUPERHEAT, EQUIVALENT HEATING SURFACE 3690 SQ.FT., BALDWIN LOCOMOTIVE WORKS
"G" ELECTRIC LOCOMOTIVE 1913, PASSENGER TYPE, SINGLE PHASE, 15 CYCLES, SERIES COMPENSATED MOTORS 2, VOLTS 15000, WHEEL PLAN 2-10-2, LOETSCHBERG MOUNTAIN RAILWAY, SWITZERLAND.
"H" SAME AS "D" BUT GEARED FOR FREIGHT WORK
"I" MODERN ATLANTIC TYPE STEAM LOCOMOTIVE, CYLINDERS 22" x 28", BOILER PRESSURE 200 LBS., SUPERHEAT, EQUIVALENT HEATING SURFACE 2400 SQ.FT., BALDWIN LOCOMOTIVE WORKS.
SPEED IN MILES PER HOUR.
0
10
20
30
40
50
60
70
5000
10000
15000
20000
25000
30000
35000
40000
A
B
C
D
E
F
G
H
I
2000 H.P.
1000 H.P.
TRACTIVE EFFORT IN LBS.
ELECTRIC MOTIVE POWER
IN THE OPERATION OF RAILROADS

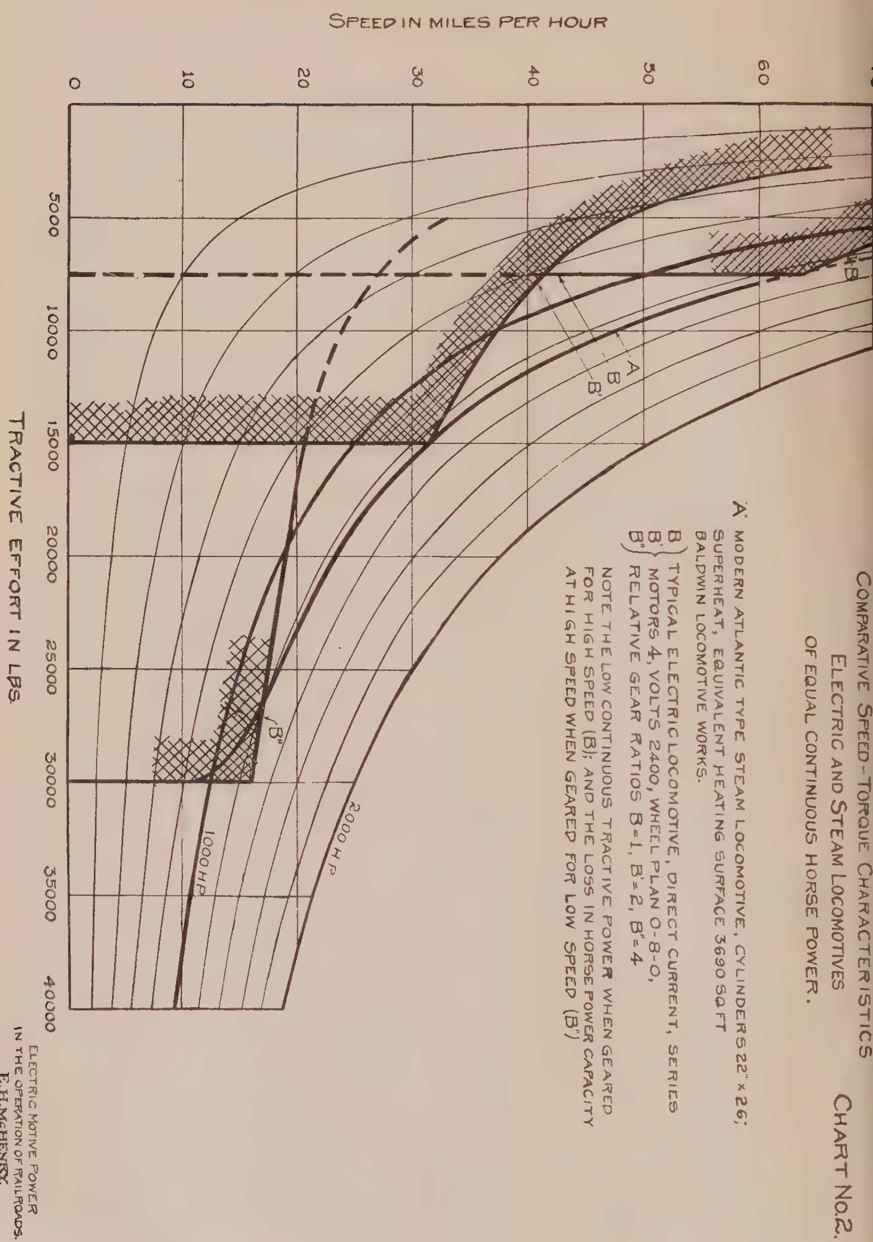


CHART No. 2.
COMPARATIVE SPEED-TORQUE CHARACTERISTICS
ELECTRIC AND STEAM LOCOMOTIVES
OF EQUAL CONTINUOUS HORSE POWER.
"A" MODERN ATLANTIC TYPE STEAM LOCOMOTIVE, CYLINDERS 22" x 26", SUPERHEAT, EQUIVALENT HEATING SURFACE 3690 SQ FT BALDWIN LOCOMOTIVE WORKS.
B, B', B" TYPICAL ELECTRIC LOCOMOTIVE, DIRECT CURRENT, SERIES MOTORS 4, VOLTS 2400, WHEEL PLAN O-8-O, RELATIVE GEAR RATIOS B=1, B'=2, B"=4
NOTE THE LOW CONTINUOUS TRACTIVE POWER WHEN GEARED FOR HIGH SPEED (B); AND THE LOSS IN HORSE POWER CAPACITY AT HIGH SPEED WHEN GEARED FOR LOW SPEED (B")
SPEED IN MILES PER HOUR
0
10
20
30
40
50
60
70
TRACTIVE EFFORT IN LBS.
5000
10000
15000
20000
25000
30000
35000
40000
A
B
B'
B"
1000 HP
2000 HP
ELECTRIC MOTIVE POWER IN THE OPERATION OF RAILROADS.
E.H.McHENRY.

tion of the principal characteristics of electric engines to the practical operating requirements.

Axle Loads.

A further and most promising opportunity is presented for reducing and limiting the present great expenditures incurred for Maintenance of Equipment and Maintenance of Way and Structures. The necessity for maintaining the rigid wheel base within reasonable limits, while meeting the demand for increased tractive power, has resulted in the imposition of concentrated loads on driving axles, which in modern engines may reach 65000 lbs. (29490 kg.) or more. The strength of rails and track has not kept pace with the increasing wheel loads, which if not unsafe are certainly very costly in construction standards and track maintenance. The rule of the Baldwin Locomotive Works for safe working limits prescribes weights of 2240 lbs. (1016 kg.) on driving wheels for each 10 lbs. (4.5 kg.) of weight per lineal yard of rail section, or for maximum axle loads of 65000 lbs. (29490 kg.) as above, 145 lbs. (65.8 kg.) rail sections are required. Rail sections in excess of 100 lbs. (45.4 kg.) are not in common use and for such sections the rule allows but 44800 lbs. (20325 kg.) per axle. While the recent development of engines of the ''Mallet'' type permits lighter axle loads for equal tractive power, it is not likely that such engines will long hold the field against their electric competitor, with their disabilities of great weight, high machinery friction and costly repairs. There is also a pronounced tendency in electric engine design to eliminate all reciprocating parts, including connecting rods, pins, jack shafts and counterweights in order to reduce wheel loads, machinery friction and maintenance charges.

Multiple Unit Control.

It is also probable that some form of multiple unit control will be developed for the operation of freight trains which will relieve and distribute the present excessive strains on draft rigging, track and bridges, which will require the equipment of freight trains with a system of control circuits. The necessity for such equipment seems close at hand, in connection with similar requirements for electric-pneumatic brake control and the growing need for better means of communication throughout the great length of modern freight trains.

Ideal Characteristics.

If we may venture to peer into the future sufficiently far to predict the development of an effective method of variable speed-torque control and of high speed motors of lighter weight and greater horse power, the general specifications of the ideal electric freight engine assume form and promise results of the greatest commercial importance and value. The value of the great reduction in train mileage and in maintenance of track and equipment which may be secured by the use of engines of the following specifications will be appreciated by all practical railway men:

Variable speed-torque control.
Electric braking and power recuperation.
Rigid wheel base, not exceeding................8′ 0″ (2.44 m.)
Reciprocating parts..........................None
Number of axles.............................Draft rigging limits
Weight on driving wheels, per axle..............40,000 lbs. (18,144 kg.)
Tractive power, 27% adhesion, per axle..........10,800 lbs. (4,899 kg.)
Horse power, continuous, per axle..............720-864 (730-876 chev)
Maximum speed, full traction rating, miles per hr. .25-30
Horse power, weight on drivers, per ton..........36-43 (40.1-48.2 chev)
Horse power, total engine weight, per ton........30-36 (32.5-40.1 chev)

In the writer's opinion there are no inherent difficulties which would make these seemingly high specifications unattainable, nor has he any good reason to doubt that such qualities will soon be forthcoming should the commercial demand for them become insistent.

ECONOMIC CONDITIONS OF APPLICATION.

Yield on Investment.

The first condition of economical electrification is of course the requirement that adequate returns shall be earned upon invested capital. In the case of new railways it must be assumed that the yield will be sufficient to justify the necessary expenditure for construction upon the most economical basis, and if electrical operation is contemplated it will only be necessary to insure that the additional savings or earnings from operation will be at least sufficient to afford a satisfactory return upon the additional cost of electric motive power. A greater

yield will be required to justify the conversion from steam to electric power on railways already fitted for steam operation, as in such case the gain must be sufficient to pay interest upon both the old and the new investments. In all cases the scale of operation must be sufficient to utilize to best advantage the large investment in power stations, lines, equipment and rolling stock, and to secure the largest possible divisor for additional fixed charges. "Railroads must have ten trains each way per day or haul 1,000,000 ton miles, total, per 100-mile (161 km.) division before electrification is practicable." — E. P. Burch. Another writer, H. W. Leonard, fixes the minimum requirement at 250 h.p. per mile of track, but there are so many modifying factors entering into the problem that no general rules can be safely accepted and the equated values of all factors must be worked out and established for each particular case. The most favorable conditions for electrification may be broadly classified under two general heads, viz: "Conditions Affecting Earnings" and "Conditions Affecting Expenses".

CONDITIONS AFFECTING EARNINGS.

Train Frequency and Speed.

Quite contrary to the generally accepted belief, the effect upon earnings is usually of much greater importance and value than that upon operating expenses, as both gross and railway net earnings may be much more affected by changed conditions of service than by mere reductions in operating expense. Light trains can be run more cheaply, which not only increases net revenues per train mile but permits greater frequency of service, which in turn reacts to increase both the volume of traffic and gross earnings. Heavy trains can be run faster, thus gaining the benefit of the higher rates for such service without unduly sacrificing train tonnage and train earnings.

Acceleration.

Higher rates of acceleration permit faster schedules in local and suburban service, which together with the greater safety and comfort afforded, and the relief from annoyances and damages incident to smoke, cinders and gases and obscuration of signals, also tend to increase the volume of traffic and the amount of gross and net earnings.

Competitive Conditions.

Unfavorable competitive conditions may be equalized or reversed and valuable advertising secured which will correspondingly affect gross and net revenues.

Multiple Track Levels, etc.

The adoption of multiple track levels and the commercial utilization of aerial rights over the track levels in the larger passenger terminals will make the large investment at such terminals more efficient and under favorable conditions the income from commercial uses may be sufficient to defray the greater part of the fixed charges on costly real estate and buildings.

Real Estate and Land Values.

A change from steam to electrical operation will also result in a great advance in the value of real estate along the line of route, which unfortunately is not shared by the stockholders contributing the capital for the improvement, and which suggests the thought that some portion of the burden of expense could be equitably assessed upon the property owners most benefited thereby. " . . . . it would not be wise to enact legislation which would compel one class of the public to pay for an improvement which would accrue largely to another class."—Report of Joint Board on Metropolitan Improvements to the Massachusetts Legislature, March, 1911.

Track Capacity.

A further and most favorable condition for electrification is afforded when the limit of track capacity is reached with steam operation. The value of the additional track capacity gained by faster schedules or by the consolidation of trains is always large and often exceeds the total cost of electrification.

Legislation.

It should be noted that the necessity for electrification is frequently occasioned by compulsory legislation or by the physical disabilities of steam operation in tunnels and terminals, quite regardless of the economical aspects.

CONDITIONS AFFECTING EXPENSES.

Economic Comparisons.

All physical and financial comparisons of steam and electric operation should be primarily based upon trains of equal

number, length and weight moving through the same distance in equal times, further subject to only such modifications as may result from inherent distinctions and features not shared in common. The general failure to observe this rule commonly results in faulty and misleading conclusions in which "electrification" is usually credited with savings due to heavier engines or to better methods of operation, which may be equally secured with either steam or electric traction. The reduction of operating expenses will be greatest under conditions of high traffic density, high train frequency and uniform distribution of traffic over time and distance, which will afford large divisors for all overhead expenses; improve the efficiency of labor and more effectively utilize the capacity of power stations and special equipment.

Train Mileage.

A large volume of freight traffic affords opportunities for utilizing the inherent possibilities of electric traction to best advantage, more particularly in conjunction with concentrated power requirements, as the saving in train miles and operating expenses effected by consolidating the traffic into fewer and heavier trains may readily be larger than that derived from any other source. Train tonnage ratings are more frequently determined by the requirements of the time schedules than by the resistance of the ruling grades and within tractive limits such ratings may be increased in almost direct proportion with the engine horse power. Also, tonnage ratings based upon full traction or adhesion ratings may be readily increased by the use of two or more engine units operated by a single crew. In either case a large saving in train miles and operating expenses should result.

Assistant Engine Service.

The higher percentage of available adhesion afforded by the uniform rotary torque of the electric engine is not yet as fully utilized as it should be, for reasons previously explained, but even with the present limitations the existence of mountain grades and long inclines requiring the use of heavy road engines and assistant engines is a favorable condition for electrification. The extra weight of steam engine and tender which is saved may be added to the train rating in the form

of commercial tonnage. Fast time schedules increase engine mileage and efficiency and also reduce overtime wages. The fuel lost by incomplete cylinder expansion and by higher machinery friction is saved. Track maintenance is much reduced and the cost of maintaining secondary engine terminals is avoided. Electric braking and, in less degree, power recuperation are included among the attractive possibilities of electric operation on mountain grades.

Terminals, Yards and Tunnels.

The advantages of electric traction in its application to large terminal and switching yards or to long tunnels have been previously noted, but in the case of large switching yards it may be further remarked that the cost of engine fuel will frequently not exceed 25% of that required in steam operation and that the better control and greater tractive power of such engines will reduce the cost of power requirements, which together with the longer hours of service, in the writer's opinion, will economically justify the electrification of isolated yards of large capacity.

Length of Division.

For the most economical results it is necessary that the zone of electric operation be extended to cover the full length of the engine stage or district and that operation within the zone be made homogeneous by the inclusion of all passenger, freight and switching service.

Engine Fuel and Repairs.

Engine fuel and engine repairs are the two largest specific items of expense in the operating accounts of steam railways, and apart from the value of train mileage which may be saved under some conditions or the effect upon gross and net earnings by changed conditions of operation, the possible reductions in these two items will in most cases determine the commercial feasibility of electric operation. A crude "rule of thumb" sometimes used by the writer for quick approximations, assumes that the fixed charges of an electric installation should not exceed one half of the cost of steam engine fuel and repairs, plus 10%. It is obvious that economic estimates will be correspondingly affected by the costs of fuel and that local conditions of cheap coal or oil fuel are unfavorable to electri-

fication. Such conclusions may be modified or reversed, however, by available sources of cheap hydro-electric power or by unfavorable water conditions, including scanty or expensive sources of supply or by scaling and foaming boiler waters, so frequently encountered on western roads. In general, the cost of steam generated electric power with coal at $1.00 to $1.50 per ton compares more favorably with hydro-electric power than is appreciated, more particularly when cheaper or uncommercial grades of coal can be burned under the boilers at the power station. The commercial efficiency of the coal used at power stations as compared with the coal consumed in steam engines is relatively very high, although burdened with large transmission and conversion losses. The ratios vary in different classes and conditions of service, but as ascertained by experience on the New Haven Road the ratio in passenger service is approximately 1 to 2; in freight service 1 to 2½ and in switching service 1 to 3.

Relative and absolute quantities of coal consumed in different classes of electric service in pounds per 1000 ton miles, (1460 ton-km.) were as follows:

June, 1914	Lbs.	
Passenger, express	95.1	(43.2 kg.)
" local	195.9	(88.9 ")
Oct.-Nov., 1914		
Freight, fast	72.8	(33.0 kg.)
" slow	78.6	(35.6 ")
" local	186.1	(84.4 ")
Switch engines, per hour	331.0	(150.1 ")

Similar comparisons of the cost of engine repairs in the same service are not satisfactory on account of abnormal local conditions, but in general it may be safely assumed that under normal conditions the cost of repairs per engine mile will not vary between one third and one half of the cost in similar steam service. The saving is of course still greater with bad water conditions. The application of these large ratios to the great cost of fuel and engine repairs may be expected to afford large operating credits applying on new fixed charges incurred. The effect of the many minor factors previously noted upon the cost of operation, while important, forms so small a factor in the final result that a further analysis need not be attempted.

CONCLUSION.

A comprehensive review of the results already obtained and of the attractive possibilities indicated by the experience of later years, leads to the conclusion that the field in which electric traction may be profitably applied is much larger than generally understood, and that there are many existing opportunities for capital investments upon a large scale which will earn from ten to twenty percent with reasonable certainty. While the art is not yet fully developed in some applications, in many others all present practical requirements may be met with added advantages of great value and profit, and there is consequently little reason to doubt a continued development and further expansion in the field of electric traction as soon as the financial and legislative conditions permit.

A few typical views showing different phases of practical electric traction, together with an extreme example of steam traction, are added for their general interest.

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EXPLANATION OF ABBREVIATIONS.

E. R. J.	Electric Railway Journal
A. S. C. E.	American Society Civil Engineers
A. I. E. E.	American Institute Electrical Engineers
E. W.	Electrical World
S. R. J.	Street Railway Journal
B. I. C. E.	British Institute Civil Engineers
A. S. M. E.	American Society Mechanical Engineers
Ry. Age	Railway Age
Elec. Age	Electric Age
A. R. E. A.	American Railway Engineering Association
C. S. C. E.	Canadian Society Civil Engineers
G. E. R.	General Electric Review
E. J.	Electric Journal
R. A. G.	Railway Age Gazette
E. R.	Electric Review

APPENDIX.

STATISTICS OF ELECTRIFICATION STANDARD RAILWAYS.

(Compiled and furnished by Edward P. Burch, Consulting Engineer, Minneapolis, Minn., September, 1914.)

Single-Phase System.

Name of Railway	General Location	Trolley Voltage	Route Miles	Track Miles	Locomotives
New York, New Haven & Hartford,	Connecticut	11,000	110	572	100
Boston & Maine,	Massachusetts	11,000	8	22	5
Norfolk & Western,	Virginia	11,000	30	75 or 85	26 or 25
Pennsylvania,	Philadelphia	11,000	20	90	0(1915)
Windsor, Essex & Lake Shore,	Canada	6,600	37	40	1
Grand Trunk,	Michigan-Canada	3,300	4	12 or 19	6
Spokane & Inland Empire,	Washington	6,600	152	*162	12
London, Brighton & South Coast,	England	6,600	60	160	0
Kiruna Riksgransen,	Sweden	15,000	81	90	15
Christiania-Drammen,	Norway	15,000	33	42	17
Thamshaven-Lokken,	"	6,600	33	36	3
Midi,	France	12,000	165	295	16 or 73
Villafranche,	"	15,000	8	8	1
Bernese Alps, Lötschberg,	Switzerland	15,000	52	55	18 or 16
Rhaetian,	"	10,000	40 or 46	48 or 186	11
St. Gotthard,	"	15,000	68 or 73	100	—(1916)
Baden State,	Germany	15,000	31	34	12 or 10
Prussian State,	"	11,000	19	50 or 100	13 or 45
Bavarian State,	"	11,000	15	16	2

* Spokane & Inland Empire has in all 216 route miles and 294 track miles.

Single-Phase System—Continued.

Name of Railway	General Location	Trolley Voltage	Route Miles	Track Miles	Locomotives
Lauban Konigszelt,	Germany	11,000	81	124	45 or 54
Mittenwald-Innsbruck,	Austria-Germany	15,000	66	69	9 or 8
Waitzen Budapest,	Austria	12,000	34	36	4
Vienna-Pressburg,	"	15,000	43	45 or 50	8
St. Polten-Mariazell,	"	6,600	63	68	14
	Total		1253 or 1264	2216 or 2426	338 or 432

Direct-Current System.

Name of Railway	General Location	Trolley Voltage	Route Miles	Track Miles	Locomotives
Baltimore & Ohio,	Maryland	660	4	10	14
New York Central,	New York	660	50	250	63
New York Central,	Detroit	660	6	20	10
Pennsylvania—					
Long Island R. R.,	Long Island	660	100	250	2
Manhattan Terminal,	New York..........	660	24	100	35
West Jersey & Sea Shore,	New Jersey	660	75	150	0
Piedmont & Northern,	Carolinas	1,500	140	160	12
Canadian Northern,	Canada	2,400	18	20	7
Michigan & Chicago,	Michigan	2,400	92	100	0
Toledo & Western,	Ohio	660	59	89	5
Illinois Traction,	Illinois	660	200	450	22
Waterloo, Cedar Falls & Northern,	Iowa	1,200	50	100	6

Fort Dodge, Des Moines & So.,	Iowa	1,200	120	145 or 126	9
Butte, Anaconda & Pacific,	Montana	2,400	30	90	17
Chicago, Milwaukee & St. Paul,	"	3,000	113	168	16
British Columbia Electric,	British Columbia	1,200	24	30	7
Oregon Electric,	Washington	1,200	154	180	10 or 9
United Railways,	Oregon	1,500	28	35	1
Portland, Eugene & Eastern,	"	1,500	95 or 122	100 or 340	3 or 2
Oakland, Antioch & Eastern,	California	1,200	100	100	4 or 3
Southern Pacific—					
Oakland Division,	"	1,200	81 or 50	121	1
Pacific Electric,	"	1,500	57	114	14
North Eastern—					
Newcastle-Tynemouth,	England	600	37	82	6
Darlington-Newport,	"	1,200	18	44 or 50	10
Lancashire & Yorkshire—					
Bury-Holcombe Brook,	"	3,500	4	4	
Bury-Manchester,	"	600	10	20	
Metropolitan,	London	660	26 or 35	59 or 70	20
London & So. Western,	England	660	25	73	0
London & No. Western,	"	660	14	79	0
Stockholm-Saltzoebaden,	Sweden	1,200	5	6	0
Moselhutte,	France	2,000	9	10	3
St. Georges-La Mure,	"	1,200	20	21	4
Paris Orleans,	"	660	14	46	11
Western,	"	660	50	130	0
Midi, near Villafranche,	"	850	35	36	0
Bernia Railway,	Switzerland	750			0
Lugano, Tesserete, Pontetrese,	"	1,000	5	6	0

Direct Current System.—Continued.

Name of Railway	General Location	Trolley Voltage	Route Miles	Track Miles	Locomotives
Milan-Porto Ceresio,	Italy	660	48	81	5
Budapest Suburban,	Hungary	1,000	123 or 55	130 or 123	12
Poprad-Csorbasee,	"	1,650	21	21	0
Melbourne Suburban,	Australia	1,200	150	323	0
	Total		2171 or 2234	3953 or 4184	326 or 329

Three-Phase System.

Name of Railway	General Location	Trolley Voltage	Route Miles	Track Miles	Locomotives
Italian State—					
Valtellina,	Italy	3,300	67	72	14
Milan-Lecco,	"	3,300	32	60	16
Giovi-Genoa,	"	3,300	13	46	65
Savona-Ceva,	"	3,300	30	33	5
Mt. Cenis,	"	3,300	11	12	5
Burgdorf-Thun,	Switzerland	750	26	28	3
Swiss Federal,	"	3,300	13 or 23	26	4
Great Northern,	Washington	6,000	4	6	4
	Total		196 or 206	283	116
	Grand total		3,620 or 3,704	6452 or 6893	780 or 877

DISCUSSION

Mr. H. J. Kennedy, referring to the author's statement, "The first commercially practical engines of this kind were operated by the Baltimore & Ohio Railroad through its Baltimore tunnel in 1905; only a few months later than the initiation of electrical service on the Nantasket Beach line above mentioned," noted an error and said that three of the five locomotives were purchased in 1894 and were of about 1000 hp.; these were, he believed, taken out of service in 1910 or 1911. The other two were purchased in 1903 and were of 160 tons each. Mr. Kennedy.

He then pointed out the following from the paper as one probable explanation why companies are holding back in electrification of their systems: "Another factor which undoubtedly exercises a deterrent effect upon the more rapid adoption of electric traction is the number and diversity of types now under trial, together with the yet unsettled opinions of the specialists in this field." Two experiments along this line are (1) the 3000-volt installation on the Chicago, Milwaukee & Puget Sound Ry. and (2) the single-phase three-phase system on the Norfolk & Western Ry.

The reference to the mercury-vapor converter experiments, the speaker thought, refers to a locomotive experimented with on the N. Y., N. H. & H. R. R.

Mr. W. J. Davis, Jr.,* Mem. A. I. E. E., said that power companies can afford to give a very low price on power due to the very low load factor. This has been done on the C. M. & P. S. Ry., where power has been purchased for 0.6 cent per kw-hr. Some companies have offered power at the low rate of 0.5 cent per kw-hr. This is possible because the high load factor of extensive power companies will give them a chance to absorb heavy loads carried by mountain electrifications. Cost is the controlling factor, whether the railroad makes or buys its power. Mr. Davis.

Mr. G. M. Eaton,† Mem. A. I. E. E. (by letter), called attention to the author's reference to the practice of working electric switching locomotives in yards continuously, in one case for 30 days without attention. If this practice is economy, it is so in spite of the heavy maintenance charges that are sure to be eventually incurred. Incipient failures are usually easily detected, and a comparatively small amount of attention in the early stages of deterioration will place the equipment in first-class condition. Mr. Eaton.

The same principle is involved in connection with annual overhauling, to which the author refers on page 606. If the margin in favor of electrification of a steam road is so narrow that the estimated expense of an annual overhaul of the electric locomotive has an appreciable influence in deciding whether to electrify or not, then continue steam operation. Having actually electrified, the conservative practice is to overhaul annually

* Pacific Coast Engineer, General Electric Co., San Francisco, Calif.

† Eng., Railway Division, Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.

Mr. Eaton. for a few years, and after finding the overhaul actually useless, extend the overhauling period gradually till the logical period is determined.

The author refers to the high adhesion possible with electric locomotives. This high adhesion must be reckoned with in proportioning the parts to insure sufficient strength. It is, however, necessary to advance slowly in guaranteeing to make use of this high adhesion in actually pulling trains on mountain grades. The rail conditions are very varied, and data are yet incomplete on the maximum safe pulling adhesion of an electric locomotive.

The theoretical ability of the electric locomotive to start heavier trains than a steam locomotive of equal adhesive weight undoubtedly exists, and a certain amount of progress may be looked for in capitalizing this feature.

Referring to the heading "Diversity of Types," railroad electrification shares with other large problems the advantage of different possible solutions. It has been conclusively proved that various systems possessed sufficient advantage over steam to justify the expense of electrification. The ultimate best electrification will never be attained as long as there are men striving for improvement.

The steam locomotive has advanced more in the last ten years than at any other equal period in its history, and electric locomotives and railway electrification may confidently be expected to advance greatly year by year.

Reference is made to the increasing complexity of system. In this connection it is very interesting to note that the first trunk-line locomotives built by the Baldwin Westinghouse interests are the most complicated they have ever turned out, being designed for A.C.—D.C. operation. In spite of their complexity, however, the locomotives are now in their tenth year of successful service.

The author also refers to the demand for more highly specialized and better paid labor, presumably as compared with steam locomotives. When a steam railroad is electrified, the senior steam engineers quite generally select the electric runs. They are, as a class, ambitious to master the machines, and prove themselves capable of doing so. Very thoroughly organized instruction is always necessary, and no man can be a competent steam man today and an expert operator of an electric locomotive tomorrow without painstaking study. The point remains, however, that it is not a different class of labor, but the same individuals who operate the electric motive power.

In connection with multiple-unit control, consideration was given seven or eight years ago to the feasibility of hanging a control cable to cars intervening between locomotives in a long freight train.

If one could imagine the adoption of a standard control train line, it might be legislated into existence as a necessary part of freight car equipment. The whistle and shock method of control, with a locomotive that can hang at a standstill for one minute, seem, however, to be too success-

ful to warrant the expenditure involved in a more complicated system. This is true even where mountainous country confuses the whistle alone because of echoes. Mr. Eaton.

The variable-speed torque control, referred to in the paper, is an ideal which has been earnestly sought. Every known type of mechanical and other speed-changing device has been investigated, only to find some prohibitive feature, such as cost, weight, space, or maintenance, etc. This search is still active, and when it is successful, the cause of railroad electrification will receive a great impetus.

Mr. Kennedy was correct in his opinion that the mercury-vapor converter experiment was conducted on the N. Y., N. H. & H. R. R.

It must be realized, however, that this adaptation of the single-phase system is at present entirely in the experimental stage, and while the results of the experiments made are very gratifying, no estimate of the time when it will become commercial can be attempted.

Regeneration is not economical unless you have a load to absorb the regenerated power; this in some cases has been taken up by rheostats. However, the great gain is in the safe and automatic control and the saving in the wear of brake shoes and tires; also in the elimination of brake-shoe dust.

Mr. Paul Lebenbaum,* Mem. A. I. E. E., said that Mr. Eaton was very conservative in speaking of regeneration of power, for regeneration is a great argument in favor of electric power, as on a steam road it cannot be accomplished. Mr. Lebenbaum.

Mr. H. Y. Hall,** Mem. A. I. E. E., said that the reason why the power companies are not furnishing the railroads with power lies in the fact that the power companies will not give a reasonable rate, together with continuity of service. Mr. Hall.

Mr. A. H. Babcock,*** Mem. A. I. E. E., said that on the Southern Pacific electric lines the engineers' seniority controls the selection of runs. If a steam man wishes to have an electric run and has the seniority to enforce his desires, he first attends a school of instruction, and, after qualifying, he can "bump" any man with less seniority than his out of a run and take it for his own. Mr. Babcock.

As a rule the steam engineers qualify without difficulty, but while they learn easily they are apt to forget easily, because, having much less to do than when on steam locomotives, their minds are not so actively employed and, consequently, from time to time reinstruction is necessary.

With reference to Mr. Eaton's question in regard to multiple operation of steam locomotives: It is the practice on the Sierra Nevada grades to place locomotives about thirty car lengths apart, this being approximately the maximum distance whistle signals can be heard distinctly in the snow-

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Mr. Babcock. sheds. When the head man is ready to leave a station he whistles to the rear man, who answers, and then pushes up all the slack he can until he comes to a standstill with his throttle open; the head man then moves ahead, and when he has pulled out enough slack to relieve the rear man, the train moves out. In coming to a stop the reverse procedure is used—the head man shuts off and when the rear man finds he can go no further he shuts off too. Often, in the handling of heavy trainloads in this manner, the engines will stand three or four minutes against the load with the throttle open nearly to the slipping point of the wheels.

In the study of any mountain or other main-line electrification, a comparison of many points of view is necessary before conclusions can be reached with respect to the most economical method. Two of the elements entering into this problem are popularly very much misunderstood. The first is the factor of regeneration of power on descending grades. The actual power return by any such system is of extremely small importance as compared with the advantages secured in other directions, namely, better control of the train on heavy grades and a diminished heating of wheels and axles, and consequent accidents arising therefrom.

The other point is the effect on any such problem of alleged very cheap water power. In many cases if the power were delivered free to the locomotives, it would not change in any material degree the economic problem of electrification. Furthermore, it makes practically no difference in the problem whether the power is purchased from a power company or whether it is developed in plants owned by the railroad company, for the very simple reason that a change in ownership of power sources cannot change the load factor of the railroad. In other words, the fixed charges must be paid by someone in the beginning, and always, eventually, by the consumer.

And, finally, the much discussed diversity factor does not affect this problem materially, because the railroads by no possibility can change the flow of their passengers or freight with respect to time of day or season of the year, and the peak loads must come when they will, not always as is desired. Therefore, any source of power suitable for railroad use in any serious problem must contemplate the handling of maximum demands at any time.

The railroad companies are not opposed to electrification in itself, but people with power to sell, or machinery to sell, or both, who have urged upon the railroads so forcibly consideration of electric methods, as yet undeveloped and to be financed, give, in support of their views such extravagant claims for economies that the railroad companies conservatively are asking for very complete demonstrations before risking large sums of money in such improvements. As far as can be ascertained, no railroad company is opposed to real economies, and many of them open freely their financial and statistical records to all competent students in order that they may be shown where such economies can be found. And it is significant that those engineers in this country who have made the

most extensive study of the problem are the least enthusiastic as to immediate electrification in general. Mr. Babcock.

Mr. Howard Stillman,† Mem. Am. Soc. M. E., concurred with Mr. Babcock that it is impossible for power companies at the present time to assume the necessary peak load caused by blockades. Mr. Stillman.

Mr. E. H. McHenry, in closing, accepted Mr. Kennedy's corrections, as the date of initial operation of electric service through the Baltimore Tunnel was erroneously given as 1905, instead of 1895; and also as the author had not been advised that any of the earlier engines had been taken out of service. Mr. McHenry.

Referring to the comments by Mr. G. M. Eaton, the author said that in referring to the continuous operation of electric switching engines for thirty days or more, it was not intended to imply that this was good practice, but rather as indicative of the comparatively small amount of attention required by electric engines, as compared with steam locomotive engines; nor was it thought that the cost incurred in the general overhauling of engines could be escaped, but that the time interval between general repairs would be increased and possibly wholly obviated by current "running repairs". The ability to quickly replace damaged motors, transformers and other large parts without taking the engine out of service for long intervals of time makes this at least possible.

The author's reference to the utilization of a higher percentage of adhesion has apparently been misunderstood, as the uniform rotary torque of the electric motor makes it possible to obtain 20% more effective adhesion within the present maximum limit in steam service, which is reached four times in each revolution, with the uneven angular moments of crank-driven axles. The author referred more particularly to the complexity of electric systems, rather than to that of electric engines, which must be considered self-evident; and in his reference to the demand for more highly specialized and better paid labor, had more particularly in mind the additional requirements imposed by the maintenance and operation of power houses and of the transmission and distributing systems. No necessity has been found in practice for better paid or more intelligent labor in operating electric locomotives than is already afforded by the present steam engineers, when specially instructed.

It is the author's belief that the variable speed-torque control is much closer at hand than realized, as such possibilities in connection with the further development of field speed-torque control are quite promising. The economic value of regenerated power was at first much overvalued, but there has been of late a tendency to go to the opposite extreme. Quite apart from the incidental considerations mentioned by Mr. Kennedy, the commercial value of regenerated power may be very large, as it increases very rapidly with rate of grade, length of incline, density of traffic and length of route.

Regarding the comparative value of steam and water power, as noted

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Mr. McHenry. by Mr. A. H. Babcock, "it makes practically no difference in the problem whether the power is purchased from a power company or whether it is developed at plants owned by the railroad company"; but as the first case is usually associated with long-distance transmission, more particularly in the utilization of hydroelectric power, there is frequently a difference in fact, due to the serious effect upon transmission charges and transmission losses under conditions of fluctuating load.

The author also finds it difficult to accept the statement that "Railroads by no possibility can change the flow of their passengers or freight with respect to time of day or season of the year, and the peak loads must come when they will, not always as desired", as it is quite evident that the track capacity in large measure fixes a maximum limit, which automatically tends to avoid high peak loads by distributing the power demand over more time during hours of maximum traffic, and much more can be done in the same direction in fixing time schedules and dispatching trains.